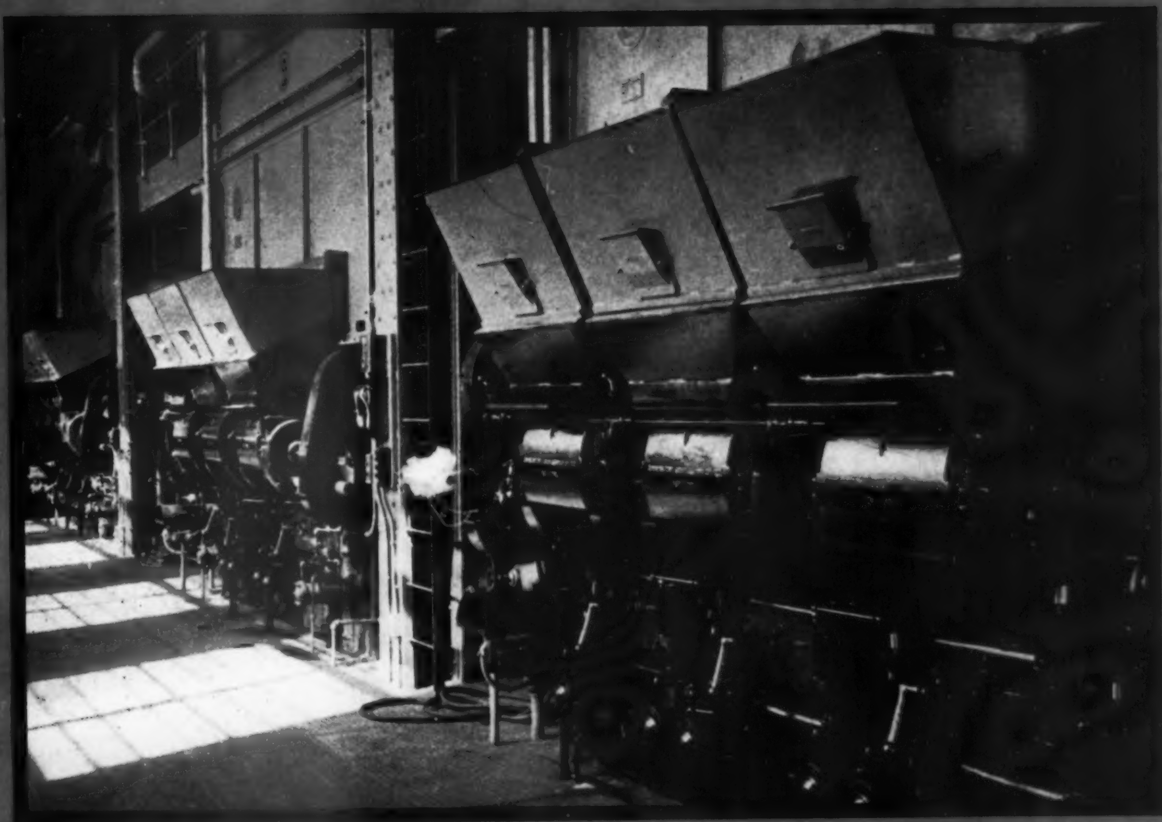
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

June, 1943



Firing aisle in defense plant showing modern spreader stoker installation

Spreader Stokers Supplement Traveling Grates for Rapid Pickup in Load

Removal of Water-Insoluble Turbine Deposits by Caustic Washing

Slip Velocity in Boiler-Tube Circuits

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DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME FOURTEEN NUMBER TWELVE

CONTENTS

FOR JUNE 1943

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

Women in Engineering Roles

Recent figures released by the Manpower Commission indicate that employment of women in war plants and essential industries has already passed the fifteen million mark, and it is predicted that an additional two million will be required by the end of the present year, as more and more married men of military age are inducted into the Armed Services.

Employment of women outside their traditional spheres was at first believed unlikely to extend appreciably to engineering lines, but events have not borne out this assumption. Today, thousands of women are engaged in engineering occupations as calculators, draftsmen, inspectors and in testing work, and the Government is establishing further short intensive courses for women in certain engineering lines. From all accounts they are performing these duties creditably. While such work, in general, involves specific training rather than fundamental engineering education, it may presage a greater future enrollment of women in engineering schools.

Furthermore, in the field of power plant operation, which was long considered to be strictly a man's job, the sight of women operators, even in some of our large high-pressure stations, has now passed the stage of novelty. Many are to be found attending auxiliaries, reading instruments, watching over control boards and serving on the turbine-room floor.

Obviously, in such cases responsibility and direction rests with a few men whose experience dictates what is to be done, particularly in emergencies; but the success attendant upon the employment of women for certain operating duties indicates that careful selection, intelligence and adaptability may offset lack of previous experience for these junior positions. The extent to which these emergency measures may leave a permanent imprint on power plant personnel is difficult to foretell at present, but they are likely to endure to some extent.

An Outstanding Accomplishment

Electric energy demand, according to the Federal Power Commission, is now nearly 19 per cent greater than it was a year ago and the peak demand has increased 15.6 per cent. These figures are considerably in excess of the average for the preceding twelve months. Yet, because of cancellations of orders and the diversion, by Government directive, of much power equipment to special war plants and for export to allied nations, the scheduled additions to utility generating capacity for this year will amount to only 2,696,000 kw. This is barely 6 per cent of the present installed capacity. Furthermore, the utilities, as a whole, are reported by the E.E.I. to be operating with 24 per cent fewer employees than they had a year ago.

This is unique in that the electric utilities represent probably the only essential industry that has been able to meet the war demands without large expansion in both plant and personnel. Although electricity is basic to both war and civilian needs, it is one of the few commodities which, thus far, it has not been necessary to ration.

The record is one that reflects outstanding credit upon both the management and the engineers in that industry, as a marked contribution to the War Effort.

Reflections on the Coal Controversy

With the return of the miners to their work on June 7, after a week's suspension in coal production, some solution to the controversy seemed assured. Although the country at this time could ill afford even a week's loss in coal output, estimated at eleven million tons, the equivalent of sixteen billion kilowatt-hours at the present average utility rate, it was fortunate that the stoppage came at a time of seasonal decrease in the rate of consumption—a period which provides opportunity to replenish stockpiles and thus ease the later transportation burden.

Stocks of coal held by large industrials and electric utilities, as of May first, were somewhat greater than on April first and represented an average, for all classes of consumers, of forty-nine days' supply as compared with forty-five days at the earlier date; but this differential was more than offset by the stoppage. Moreover, storage along the Great Lakes is forty-five per cent less than it was a year ago.

There have been many repercussions from the mining situation at this critical time, one of which became apparent in the psychological effect on those contemplating further conversions from oil to coal. The ability of manufactures of coal-burning equipment to meet deliveries is a matter of the timing of orders, and now is the time for planning such conversions so that equipment may be ready when the heating season starts.

It is regrettable that periodic disturbances in the coal situation seem inevitable every time a new contract between miners and operators comes up for negotiation. Whatever the terms of the solution to the present controversy, they are certain to involve higher production costs which will be reflected in higher prices to the consumer, inasmuch as the recent re-enactment of the Bituminous Coal Act protects the operators. Such being the case, still greater stress will be placed on operating economy in power plants. This will apply also to conversions which should be planned on the basis of long-term investments, through the selection of firing equipment and controls that will insure efficient performance and minimum manual labor.

Spreader Stokers Supplement Traveling Grates for Rapid Pickup in Load

By H. G. MEISSNER and M. O. FUNK
Combustion Engineering Company, Inc.

Changing industrial conditions in the territory served necessitated the revamping of this plant to secure greater capacity, and more rapid load swings, with reduced maintenance. Removal of existing refractory arches and the installation of water walls, the addition of spreader stoker units in the rear walls and over-fire air, have accomplished the desired results with the use of a minimum of critical materials.

THIS 600-lb station, constructed some years ago and lately extended through the addition of a high-pressure unit, serves a combined industrial and residential area in the Middle West. The characteristic load shows a marked morning peak and a secondary afternoon peak, these load swings being taken by the units indicated in Fig. 1, together with a similar group of adjacent units. Operating procedure requires that the units shown be taken out of service every night as the load falls off, the boilers being carried on hot bank until returned to service in the morning; the evaporation is then increased in small increments until the morning peak is reached.

Boiler operation of this character requires firing equipment that can be banked easily, be brought into service rapidly and be varied continuously in output. The traveling grate stokers serving the original boilers having refractory furnace walls, could be banked easily but required relatively long preparation for taking over load and were somewhat slow in responding to changes in steam demand, which amounted to 30,000–35,000 lb per boiler, within a few minutes' time. Also maximum stoker rating was limited by refractory maintenance, which became excessive with continuous boiler outputs above 120,000 lb of steam per hour. Data on the original boilers and stokers are contained in Table 1 and a section through the furnace is shown in Fig. 2.

To meet these increased operating requirements it was decided to supplement the traveling grate stokers with stokers of the spreader type firing over the existing fuel beds. It was deemed advisable to retain the traveling grate stokers to carry the base load and for their banking characteristics, with the spreaders providing increased capacity and flexibility in response to steam demands. Also, water-cooled surface was added to the furnace to permit increased capacity without excessive furnace maintenance. The arrangement ultimately chosen is shown in Fig. 3 and described in Table 2.

Briefly, the revised arrangement includes a traveling grate stoker in an open water-cooled furnace with four mechanical spreader units mounted over the discharge end of the traveling grate. This has eliminated the suspended refractory arches extending into the furnace. Means for introducing secondary over-fire air were included. This air is supplied by a motor-driven fan capable of delivering 5100 cu ft of air per minute at 100 F against a static head of 15 in. wg. Discharge is into front

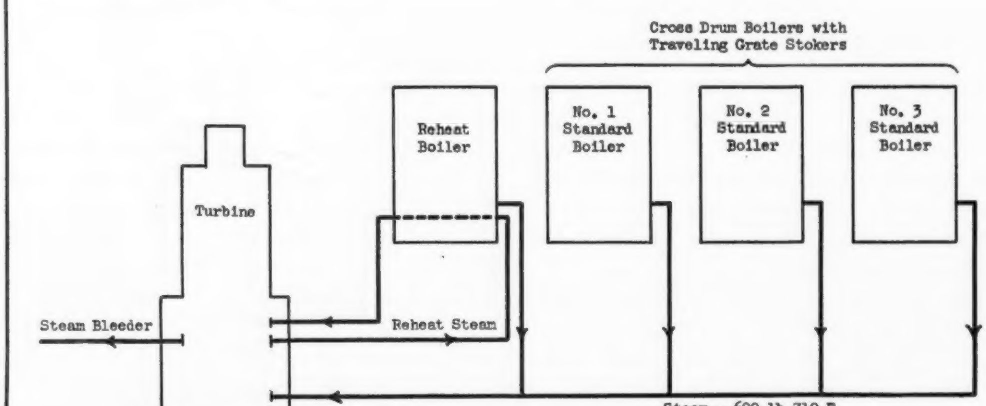

Fig. 1—Diagrammatic arrangement of boilers serving reheat turbine

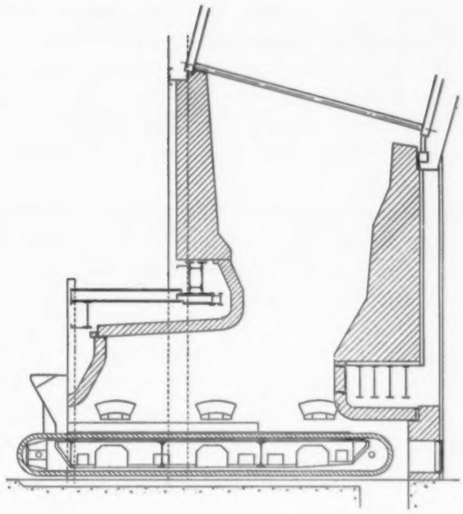

Fig. 2—Cross-section through furnace of original boiler units Nos. 1, 2 and 3

and rear ducts as indicated in Fig. 3. On No. 1 boiler, which was the first to be put into service with these changes, the air was carried from the duct at the front of the furnace through the wall by $2^1/_2$-in. extra-heavy pipes on $20^1/_2$-in. centers. However, on the second boiler this arrangement of pipes was supplemented by $1^1/_2$-in. pipes located between the $2^1/_2$-in. pipes. Reasons for the addition of these pipes will be discussed later.

At the rear of the furnace the over-fire air is carried from the duct through the furnace wall by $2^1/_2$-in. extra-heavy pipes on 21-in. centers. The intake to the fan is connected to a duct leading across the back of the furnace. This serves both to preheat the air and to assist in cooling the rear wall, which is the only refractory wall.

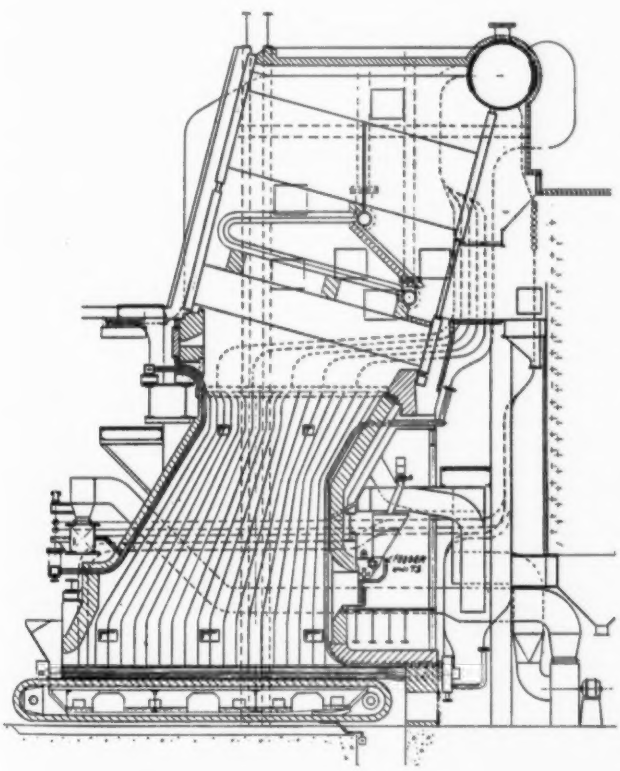

Fig. 3—Cross-section through revamped units Nos. 1, 2 and 3

The coal hoppers for the Coxe stokers are supplied through the original coal scales and swing spouts, and the coal for the spreader distributing units is supplied by means of bulk flow conveyors which pick up coal beneath the coal scale and discharge into the hoppers at the rear of the boiler. The capacity of this conveyor system on No. 1 boiler was originally $2^1/_2$ tons per hour, but subsequent operation indicated the advisability of increasing this in order to increase the fuel burning capacity of the spreader stokers. On the No. 2 boiler the capacity of the conveyors was made 5 tons per hour and that on No. 1 boiler was similarly increased during the changes on No. 2 boiler.

At this writing No. 1 boiler, as altered, has been in operation seven months and No. 2 boiler two months, No. 3 boiler is now being changed. Early performance of both No. 1 and No. 2 units has been excellent and such limits in capacity and flexibility in boiler operation as have been encountered have been dictated by other than the firing equipment.

As previously mentioned, the coal conveyor system supplying the spreader section of No. 1 boiler had an initial capacity of $2^1/_2$ tons per hour, corresponding to an evaporation of approximately 35,000 lb of steam per hour. With the traveling grate speeded up to operate at a rate such as to produce an evaporation up to 125,000 lb per hour,[1] it was possible under these conditions to raise the total evaporation to this figure, with the aid of the spreader stoker, within three minutes. The prescribed operating procedure was as follows:

When load increases were anticipated, the spreader units were kept ready and rapidly brought into service as the steam demand increased; the traveling grate being speeded up meanwhile. The spreader units were then taken off slowly and the difference was taken up by the traveling grate. The spreader stoker was then ready for the next increase.

The reverse procedure was followed when decreases in boiler rating were anticipated. Operation of this kind, however, did not take full advantage of the flexibility of the spreader units. It was evident that an increased fuel supply to the spreader stoker units, beyond the limitations imposed by the conveyor, would permit an operating procedure that would take greater advantage of the available flexibility.

When the No. 2 unit was put into service the conveyor system to the spreader section was given a capacity approximately equivalent to 70,000 lb of steam per hour. It was then possible to increase or decrease the boiler evaporation at a rate of 35,000 lb per hour in 3 minutes or 70,000 lb per hour in six minutes. This rapid an increase, however, was not considered practical for existing related equipment. The rate of change in evaporation was therefore held to 20,000 lb per hour in four minutes. With this type of operation, the spreader units can be kept in continuous service and ready at all times for a change in steam demand, either increase or decrease. As related equipment is improved to accommodate greater rates of

[1] In all the tests of capacity and flexibility made thus far, it has been necessary to estimate evaporation as indicated by meters measuring the flow of feedwater to the boilers and indicating the water level in the boiler. All estimates have been conservative. During one series of observations of No. 2 stoker water flow to the boiler varied as shown on the chart, Fig. 4, when the spreader units were put into and taken out of service at different rates between 10:00 and 10:20 o'clock. During this interval the water level in the boiler was continuously above normal.

change in evaporation, the firing equipment will be operated in a manner which will take maximum advantage of the available stoker flexibility.

Performance of the revamped firing equipment is shown in Table 3. This performance was determined by a 76-hr run on No. 1 boiler and an 8-hr run on No. 2 at different points of evaporation.

Maximum capacity tests on both these boilers were limited by practical consideration of their performance in respect to the remainder of the station. No. 1 boiler was operated at an evaporation of 157,000 lb per hr for 76 hr, and No. 2 boiler at an evaporation of 170,000 lb per hr for short periods. These figures compare with the 120,000 lb per hr continuous load of the original firing arrangement.

Maintenance of the water-cooled side and front walls need not be considered as a limiting factor in determining maximum evaporation, and maintenance of the refractory rear wall can be held to a minimum by proper use of over-fire air. By varying the static pressures in the front and rear over-fire air ducts the flame can be moved toward the front or rear of the furnace. It is desirable to keep the flame well distributed throughout the furnace and at the same time to avoid flame impingement on the rear wall. Impingement on the rear wall will tend to increase slagging and maintenance, but by properly controlling the position of the flame the maintenance should not be excessive even at high ratings.

Before the second stoker was put into service, the number and shape of the front over-fire air nozzles were changed in order to eliminate a tendency observed with No. 1 boiler for smoke to leave the furnace adjacent to the front wall. The second arrangement of nozzles was much more effective in reducing this smoke. Control of smoke discharge from the stack, though never difficult, is no longer a problem. No. 1 boiler will be similarly altered. The most satisfactory use of the over-fire air as determined during operation of No. 2 boiler is indicated in Table 4.

An interesting feature of this improved furnace and stoker design is the ease with which ignition is maintained with rapid load changes in an open water-cooled furnace. With the spreader stoker distributing coal over the entire grate surface, ignition is established close to the feed gate at grate speeds which, without the spreader stoker in operation, result in loss of ignition.

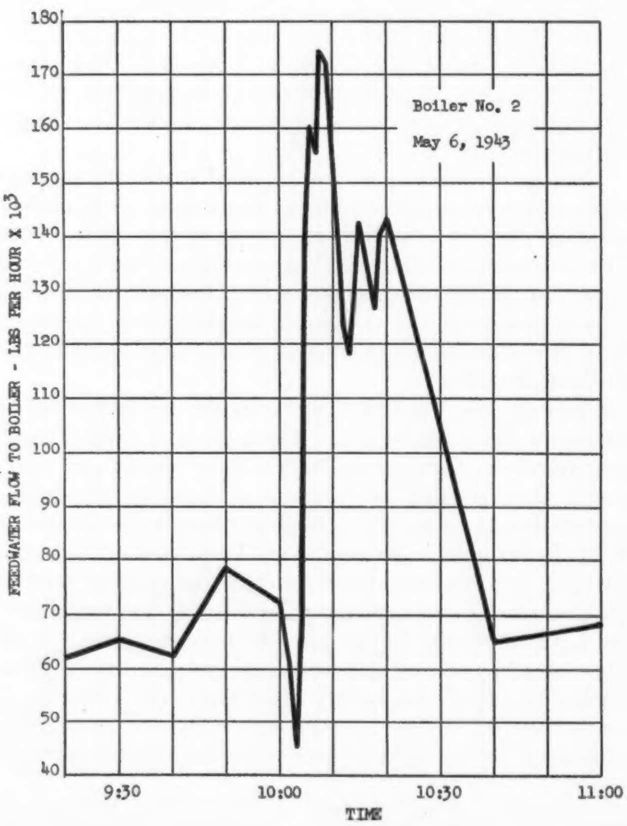

Fig. 4—Typical curve showing rapid load swings made possible by the combination of spreader and traveling-grate stokers in an open water-cooled furnace

TABLE 1—ORIGINAL BOILERS AND STOKERS

Boiler: Cross-drum, straight-tube—heating surface	14,086 sq ft
Superheater: Interdeck, convection type—heating surface	1740 sq ft
Economizer: Heating surface	8837 sq ft
Air Heater: Heating surface (external)	10,291 sq ft
Steam conditions	
Working pressure	600 lb per sq in.
Steam temp.	725 F
Normal capacity	110,000 lb per hr
Maximum capacity	120,000 lb per hr
Stoker: Coxe traveling grate, effective grate surface	356 sq ft

TABLE 2—REVAMPED BOILERS AND STOKERS

Boiler: Cross-drum, straight tube—heating surface	14,086 sq ft
Superheater: Interdeck, convection type—heating surface	1740 sq ft
Economizer: Heating surface	8837 sq ft
Air heater: Heating surface (internal)	9544 sq ft
(external)	10,291 sq ft
Water wall furnace:	
Side wall—plain tubes	
Front wall—finned tubes	
Rear wall—risers only	
Center wall—offset finned tube clinker chills	
Total heating surface	1075 sq ft
Steam conditions	
Working pressure	600 lb per sq in.
Steam temp.	725 F
Normal capacity	124,000 lb per hr
Peak capacity	165,000 lb per hr
Stoker: Coxe traveling grate—with 4 C-E spreader units set over the discharge end of the traveling grate	

TABLE 3—PERFORMANCE AFTER CHANGES

	Boiler No. 1	Boiler No. 2
Steam flow, lb/hr	157,119	99,720
Superheat pressure, lb/sq in	599.4	598.7
Superheat temp., deg F	662.4	654.7
Feedwater temp., deg F	225	207.6
Coal consumption, lb/hr	22,956	14,250
Heating value of coal, Btu/lb	9708	9687
Exit gas temp., F	325.2	298.5
CO_2 at boiler outlet, %	13.5	12.1
Total heat in steam, Btu/lb	1328.6	1323.3
Heat in feedwater, Btu/lb	193.0	175.6
Heat input to steam, Btu/lb	1135.6	1147.7
Heat input to steam, million Btu/hr	178.42	114.45
Total heat released, million Btu/hr	222.86	138.04
Efficiency,* %	80.06	82.91

* The efficiency would have been substantially increased had cinder recovery been installed, as is the case in many spreader-stoker installations.

TABLE 4—OVERFIRE AIR DATA, BOILER NO. 2

Steam flow, lb/hr	65,000	100,000	148,000
Total air required, lb/hr	95,310	156,930	218,000
Front overfire air, lb/hr	4455	6014	6324
Rear overfire air, lb/hr	4229	6558	5088
Total overfire air, lb/hr	8684	12,572	11,412
Total overfire air, % total air	9.11	8.01	5.23

Heat Storage a Factor in Load Variation

A discussion of the effect of the heat stored in the furnace and boiler metal as transcending flexibility in fuel feed with large load swings with pulverized-coal-fired units. Results of tests are cited to illustrate this effect.

WITH pulverized coal firing it is generally assumed that the inherent flexibility in fuel feed will afford very rapid response to large and rapid swings in steam demand. However, despite this flexibility, the response will be influenced to a greater or lesser extent, by the character of the load changes and by the amount of heat stored up in the water, in the metal of the tubes and drums, and in the furnace. Thus the design of furnace and boiler becomes a factor as well as the load.

Multi-drum boilers have greater water storage than those with single drums; bare furnace walls will not store up as much heat as covered walls, and a dry-bottom furnace does not provide as great a heat reservoir as one of the slagging-bottom type.

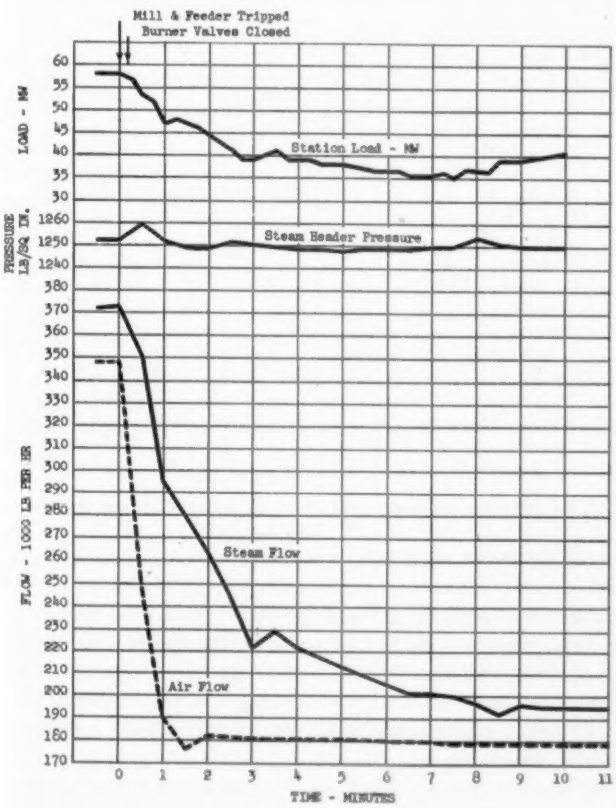

Fig. 1—Time required for steam flow to become stable with one mill tripped and the other carrying 47 per cent of load

A sudden increase in steam demand will draw upon this stored-up heat pending adjustment in fuel feed and air supply; here the stored heat helps to supply the demand pending full response of the combustion control. The reverse will hold with a sudden drop in steam demand in which case the storaged heat will keep on making steam when it is desired to cut down the output.

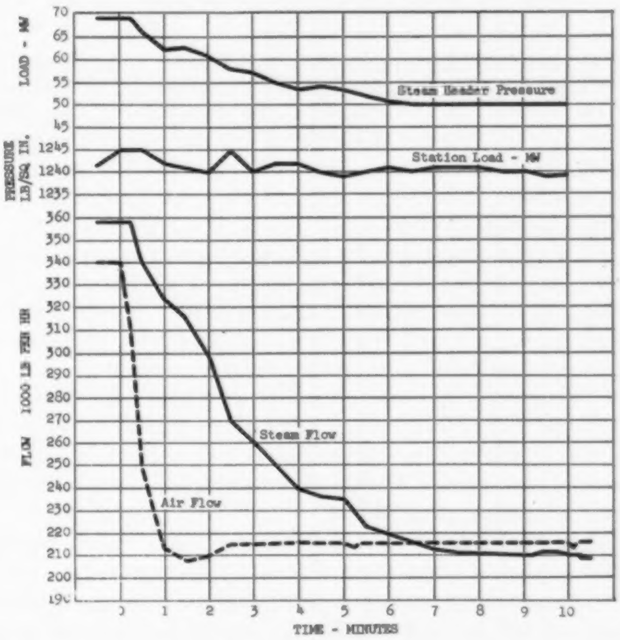

Fig. 2—Time required for steam flow curve to flatten out with both mills operating and output dropped to 60 per cent

Thus, in the first case the residual heat works with and in the second case against the objective. In the period during which the load is changing, the change in residual heat may be large compared with that supplied by the coal. It follows that the flow of steam depends upon a combination of this stored-up energy and the mill response rather than upon the latter alone. Hence, the greater the heat storage capacity of the unit, the less the relative effect of response in fuel feed as a factor in the time required to establish the required steam flow.

Heat storage within the unit may be advantageous or disadvantageous, according to the character of the load changes. With a very rapidly fluctuating steam demand of large magnitude, such as is often encountered in steel mill operation, the residual heat may be considered as analogous to a flywheel on an engine to take care of load variations and the fuel may be burned at a nearly constant rate if the periods are very short. On the other hand, where the load changes are over comparatively

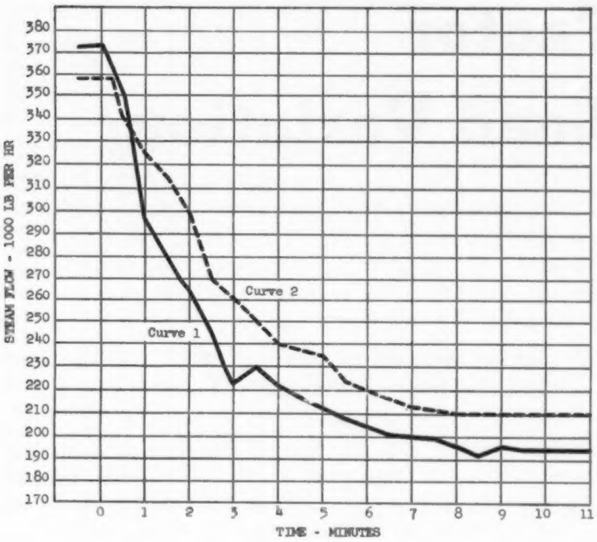

Fig. 3.—Comparison of curves in Figs. 1 and 2

long periods, such as in many central stations and industrial plants, the residual heat, while affording the combustion control time to catch up with the steam demands, may, if large, extend the time for establishment of equilibrium conditions considerably beyond that dictated by mill control.

This was borne out in tests made in connection with two large high-pressure steam generating units, having slagging-bottom furnaces, and refractory covered walls, and each supplied by two pulverizers. They were equipped with full automatic combustion control.

The station operates normally on a base load throughout the day, except for a drop of about 12 per cent at noon, at which time there is a change of around 15 lb in header pressure. The load falls off at night and one boiler is taken off the line.

The test was made to determine what might be expected should the station ultimately be required to operate on a widely swinging load, and to learn how much time would be required for the rating to be reduced to half load after the coal feed had been cut down.

On the first test, with the unit at full rating, the coal feed was reduced to 47 per cent almost instantly by tripping one mill and feeder and closing the burner valves without waiting for the mill to empty. The turbine load was reduced as required in order to maintain the header pressure as nearly constant as possible. This was done to eliminate the accumulator action in the other boiler and also so that the flow would be a measure of the boiler lag.

The air flow was reduced manually over a period of two minutes. It was not reduced instantly, as was the coal feed, in order that the steam temperature might be maintained by keeping the air flow high and allowing the CO_2 to drop from 17 to 12 per cent. The superheater damper was opened wide and the economizer damper shut as far as possible.

The result was that it required $9^1/_2$ min, for the steam flow to level out, which represented the maximum speed through which the rating could be changed from maximum to approximately half load by a corresponding cut in fuel supply. This would hold true regardless of the type of pulverizer employed. The curves in Fig. 1 show what took place under these conditions. It will be noted that the steam flow decreased rapidly for three minutes and then fell off at a lesser rate until it became steady at $9^1/_2$ min. The header pressure rose slightly during the first half minute, then became almost normal.

A second test, representing a change of almost 40 per cent in boiler rating was effected by changing the feeder speeds and exhauster damper positions on both mills, such as would occur in normal operation. As in the first test, the turbine load was reduced to maintain constant pressure to eliminate accumulator action in the other boiler. Although the magnitude of the load change was less than that in the first test, it required $7^1/_2$ min for the steam flow to level off, as will be noted from Fig. 2. The change in header pressure was small.

Fig. 3 shows a comparison of the steam flow in the two tests. In this, Curve 1 represents the lag due to the boiler with one mill tripped out and the burners shut off to reduce the coal feed instantaneously, and Curve 2 represents the combined boiler and mill lag with the feed and damper positions changed on both mills. This indicates that the mill lag is small compared with that of the boiler. In other words, the rate of change in steam flow is not much greater when the coal supply is cut instantaneously by tripping one of the mills than when the coal supply is cut by changing the mill feed.

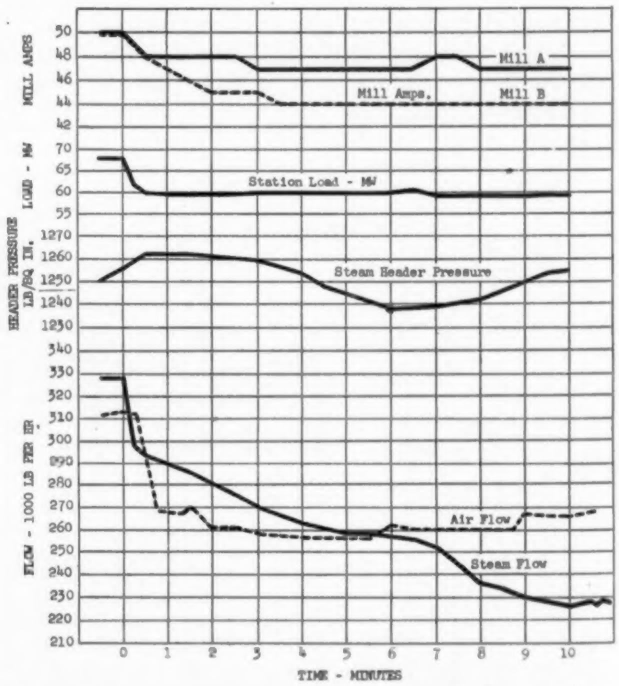

Fig. 4—Results corresponding to drop of 8000 kw in turbine load

Further tests were made to determine the magnitude of the pressure change with a rapid change in turbine load such as would occur in variable load operation. Here the turbine load was changed and the boiler controls adjusted manually at the same time to simulate automatic control.

First the turbine load was dropped 8000 kw in 30 sec and the mill feeder speeds and exhauster dampers changed at the same time. The results, which are plotted in Fig. 4, show that the header pressure rose about 7 lb

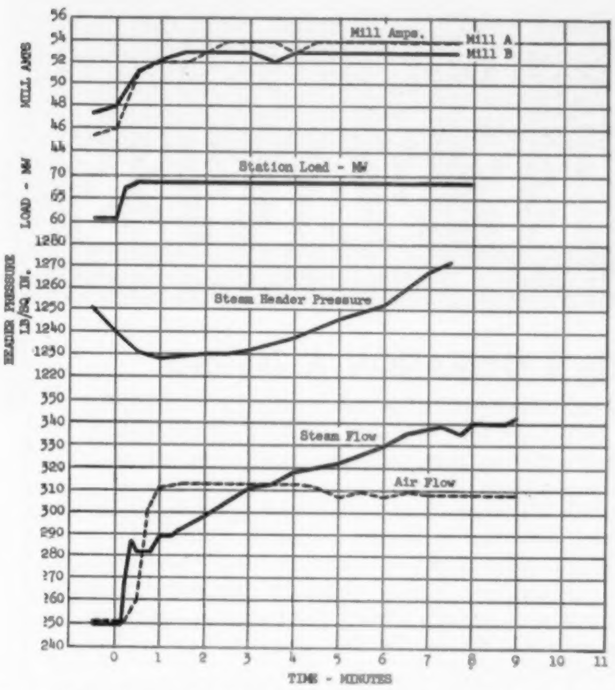

Fig. 5—Results with 8000-kw increase in turbine load

during the 30 sec, then after 2 min began to drop with decreasing steam to −12 lb at 6 min, and after 9 min was restored to normal.

Next, the turbine load was increased 8000 kw in 30 sec, the header pressure at the beginning of this test being 10 lb below normal. As before, the mill feeder speeds and exhauster dampers were changed at "zero time" (Fig. 5). It will be noted that the header pressure dropped 12 lb during the first minute and was then restored with the increase in steam flow. The rise above normal after 6 min is not indicative of anything as the boiler load was increased manually more than was necessary to balance the increase in turbine load.

From the foregoing it is apparent that while normal load swings may be handled in a reasonably brief time by the flexibility in mill control without undue disturbance in pressure, if the load swing is 50 per cent or more, the stored-up heat will transcend mill flexibility and dictate the time required to bring about the desired flow conditions. This is further accentuated if the design of furnace is such as to afford large heat storage.

Identifying Scale and Corrosion Deposits

While chemical analysis gives a general picture of the amounts of oxides present in scales and corrosion products, it does not in all cases reveal the true nature of the complex materials formed under operating conditions. Hence, it often becomes necessary to employ the polarizing microscope, the spectrograph or the X-ray to enable more correct interpretations of results. Such applications will be the subject of a feature symposium on "Identification of Water-Formed Deposits, Scales and Corrosion Products by Physicochemical Methods" scheduled for June 29 at the Annual Meeting of the A.S.T.M. at Pittsburgh. Another important part of the program will deal with determination of dissolved oxygen and include reports on work done by the U. S. Naval Experiment Station and The Detroit Edison Company.

Facts and Figures

British coal production is somewhat less than half that of the United States.

•

Use of scrap in the production of steel last year saved us 42 million tons of coal.

•

More than three thousand second-hand boilers have been put into service during the last year in war plants and other essential uses.

•

According to Secretary Ickes, conversions from oil to coal, so far, have resulted in a saving of approximately 118,000 bbl of oil per day.

•

Germany is reported to have initiated curtailment in the use of electricity for domestic and commercial use, ranging from ten to thirty per cent.

•

It is not the amount of furnace wall surface installed that determines the effective radiant heat-absorbing surface, but rather the surface of the flame envelope.

•

The Federal Power Commission reports that privately owned electric utilities paid $178,645,000 in federal, state and local taxes in the first quarter of 1943 as compared with $164,132,000 in the first quarter of 1942; which represented an increase of 8.7 per cent.

•

The reason for a tendency toward rise in drum water level with sudden demand for steam is that the drop in pressure is accompanied by the formation of steam bubbles throughout the body of the boiler water, and these bubbles have a greater specific volume than the water.

•

In the fifteen days that Maj. Gen. James Doolittle's 12th Air Force fought in the battle of Tunisia, its planes consumed enough gasoline to empty every tank in every city and village in the Northeast Coastal Area and to keep them empty for a whole month.

•

Michael Faraday is said to have been the first to resolve natural rubber into its components of carbon and hydrogen, although definite research aimed at the production of synthetic rubber was not undertaken until about 1911. This was initiated by the Russians and followed shortly thereafter by the Germans. It was taken up in the United States shortly after the close of World War I and synthetic rubber has been in commercial use here for certain products since 1932.

Removal of Water-Insoluble Turbine Deposits by Caustic Washing

By W. L. WEBB* and R. G. CALL*

The following excerpts from a paper before the Spring Meeting of the A.S.M.E. at Davenport, Ia., April 26–28, 1943, describes chemical means for the removal of water-insoluble deposits from turbine blades as successfully practiced on low-pressure machines at two power stations. By this procedure lost capacity has been regained and stage-pressure differentials restored to normal in a fraction of the time that would have been required for removing the deposits mechanically.

WATER-soluble deposits are commonly removed from turbines by reducing the inlet-steam temperature sufficiently to produce wet steam in the stages where the washing action is desired. Where a wide range of superheat control is available, this reduction may be made at the boiler. However, in the majority of installations, an auxiliary means for desuperheating the steam is necessary. Usually this is done by introduction of water through spray nozzles in the main steam line or preferably in an auxiliary line installed especially for washing the turbine. Where the steam is desuperheated in the main steam line under full temperature and pressure conditions, careful installation must be made to prevent damage to piping from thermal stress.

While washing, periodic analyses of hotwell condensate give an indication of the character of the deposit being removed from the turbine and show when further washing ceases to remove any deposit. It is good practice to isolate the hotwell condensate from the rest of the system and, where deposits are appreciable, it is advisable to dump it to waste. Provisions should be made so that vacuum can be maintained. During the washing period the turbine is operated at subnormal speed.

In cases where it is permissible for the turbine washings to be returned to the boilers, turbines have been washed satisfactorily under load. This procedure involves a number of hazards even under very careful control.

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The rotor of the high-pressure element of one of our compound units has been repeatedly washed by half-filling the turbine casing with condensate and turning the rotor by the turning gear until successive washings show no removal of solids. Care is taken that the temperature of the condensate used for washing is nearly equal to that shown by thermocouples peened into the turbine casing.

Water-Insoluble Deposits

The usual practice for removal of water-insoluble deposits consists of disassembling the unit and blasting the affected surfaces with fly ash or other suitable abrasive. In cases where deposits are extremely hard, the surfaces of buckets and diaphragm nozzles may be objectionably roughened by the abrasive. With this procedure, labor costs and capacity outages, particularly during the present war effort, dictate a search for speedier means of deposit removal.

At both high- and low-pressure plants of the companies with which the authors are associated, it has been common practice to water-wash certain turbines periodically to remove soluble deposits. Until recently there had been little difficulty with deposits not removable by water-washing. Where insoluble deposits did occur, they usually were in topping units and in such small amounts as to cause no appreciable change in turbine performance.

Windsor Plant Low-Pressure Turbines

The Beach Bottom Power Company's Windsor Plant capacity consists of four 1350-psi, 925 F boilers of approximately 750,000 lb per hr each, supplying two 60,000-kw topping units; these topping units exhausting to six 230-psi, 550 F, 30,000-kw condensing units.

The first major turbine-capacity losses occurred at Windsor following unusually heavy condenser leakage during a period when the Ohio River water used for condenser cooling contained in excess of 300 ppm of suspended matter, of which the analysis in Table 1 is typical. This high leakage made it impossible to blow down sufficiently to maintain the silica in the boiler water at its usual value of less than 10 ppm, the silica at times reaching 40 ppm. During this period, the steam quality, as indicated by conductivity measurements of gas-free samples, increased only slightly, whereas solids in the steam, determined gravimetrically, practically doubled.

Rough checks on the residue from the gravimetric-quality determinations showed it to contain almost 50 per cent silica.

TABLE 1—SUSPENDED MATTER

	Per cent
Silica (SiO_2)	22.58
Aluminum oxide (Al_2O_3)	42.06
Iron oxide (Fe_2O_3)	23.00
Calcium oxide (CaO)	0.24
Magnesium oxide (MgO)	0.18
Sulphuric anhydride (SO_3)	0.82
Organic matter	9.80
Total	98.68

Shortly after observing the higher solids in the steam, there was a slight loss in capacity both in the high- and low-pressure turbines. The nozzles on the steam-jet air pumps then became plugged and were mechanically cleaned.

Unit 5, one of the low-pressure units was disassembled about this time for removal of the fifteenth-stage buckets. There was evidence of deposits throughout this machine but they were not extensive. A sample removed from the fifteenth-stage diaphragm nozzles was shown to be similar to the deposits on the steam-jet air-pump nozzles, the analyses of both being indicated in Table 2.

TABLE 2—ANALYSES OF DEPOSITS FROM EJECTOR AND TURBINE NOZZLES

	Deposit Removed from No. 3 Air-Ejector Nozzle, April 17, 1942, Per cent	Deposit Removed from Fifteenth-Stage Diaphragm, No. 5 Turbine, April 21, 1942, Per cent
Silica	79.49	88.66
Ferrous oxide	1.07	0.86
Ferric oxide	2.10	1.56
Aluminum oxide	3.08	2.03
Calcium oxide	0.32	0.52
Magnesium oxide	0.01	0.03
Phosphorus pentoxide	0.26	0.38
Sulphuric anhydride	0.10	0.37
Sodium oxide	0.08	0.37
Organic and volatile	13.14	4.85
Total	99.65	99.63

Following the turbine inspection, the rate of accumulation of deposits proved to be greater than anticipated and, within a short time, the capacity losses on four low-pressure units totaled approximately 17,000 kw. Although the analysis of deposits, indicated in Table 2, made it appear unlikely that capacity could be regained by water-washing, this method of removal was tried without success on Unit 4, which had lost 6000-kw capacity. During the water-washing period, conductivity readings of hotwell condensate indicated that no material affecting conductivity was being removed. Because plant-load conditions would not permit extensive outages of units, attention was turned to methods other than water-washing for removal of deposits.

Reference had been made in Germany by both Geisler[1] and Goerke[2] to the use of caustic-soda solutions for the removal of silica deposits. Their practices included the spraying of a 10 per cent caustic-soda solution into the path of steam to the turbine and allowing this solution to remain in the turbine for 3 or 4 hr. Subsequent water-washing was said to have removed all deposits.

Laboratory work on the Windsor steam-jet air-pump nozzles indicated that if they were immersed in a boiling 10 per cent caustic solution for an extended period and then washed with water, the deposit was not removed. However, if the nozzles were maintained at a temperature considerably above the boiling point of the solution and then were repeatedly wetted with the 10 per cent caustic solution and allowed to dry for about 15 min after each application, the deposit was readily washed off with water.

The results of these experiments were put into practical use in caustic-washing Windsor low-pressure Unit 4 in May 1942. The below-seat drain of the turbine stop valve was replaced with a line for introduction of a 10 per cent caustic solution at a rate of about 2 gpm. While sufficient steam was admitted to hold the turbine speed between 100 and 200 rpm, the caustic solution was injected until the hotwell condensate, being dumped to the sewer, showed phenolphthalein alkalinity. This required about 45 min. The stop valve was then closed, and the caustic solution allowed to react with the deposits for a period of about 15 min after the unit came to rest. During the introduction of the caustic solution, the approximate steam conditions at the inlet to the stop valve were 230 psi, 550 F, and beyond the caustic injection point were 140 F to 200 F at a pressure slightly higher than the condenser pressure of 5 psia.

Eight additional 5- to 10-min shots of caustic solution were introduced while sufficient steam was being admitted to hold 100 to 200 rpm, each followed by the 10- to 15-min reaction period. The entire caustic-washing period required about 3 hr and consumed 350 lb of flake caustic soda.

Steam was then admitted to the unit to maintain 100 to 200 rpm, and condensate was injected at the caustic-solution injection point at a rate of about 2 gpm. After a 3-hr washing period, the hotwell condensate showed approximately normal conductivity and the unit was then returned to service.

Prior to caustic-washing, the maximum load obtainable from the unit was 27,000 kw with both control valves wide open. After washing, the unit was brought to a load of 33,000 kw, which is the limiting load, although the secondary valve was not in its full-open position. The stage-pressure data, shown in Table 3, indicate general distribution of deposits throughout the unit prior to the washing operation. In interpreting these data, it should be observed that, at a load of about 27,500 kw, the secondary control valve admitting main steam to the fifth stage was wide open before washing, whereas after washing it was only partly open.

TABLE 3—WINDSOR LOW-PRESSURE UNIT 4; CONDITIONS BEFORE AND AFTER WASHING

	Before Washing				After Washing
	4/30/42	5/1/42	5/4/42	5/5/42	5/12/42
Load, kw	27,830	27,560	27,440	27,410	27,400
Condensate flow, M lb per hr	345.67	330.8	334.8	332.9	313.5
Throttle steam temp, F	571	608	566	577	569
Throttle press., psia	253.7	251.2	253.1	251.7	257.2
Turbine head press., psia	237.8	236.1	236.1	235.1	240.0
Fifth-stage press., psia	235.3	233.6	234.4	232.8	184.1
Eleventh-stage press., psia	57.0	56.6	56.1	56.8	44.7
Thirteenth-stage press., psia	18.75	18.50	18.80	18.70	16.30
Condenser press., psia	0.57	0.66	0.80	0.82	0.66
Stage press. differences, psi:					
Turbine head to 5th stage	2.5	2.5	1.7	2.3	55.9
5th to 11th stage	178.3	177.0	178.3	176.0	139.4
11th to 13th stage	38.3	38.1	37.3	38.1	28.4
13th stage to condenser	18.18	17.84	18.0	17.88	15.64

During the washing operation, samples of hotwell water were taken at intervals for analysis. These analyses included material removed both from the turbine, and the condenser and indicated the silica concentrations,

[1] "The Desilification of Feedwater of the High-Pressure Plant in Hochet," by W. Geisler, *Vom Wasser*, 12 381–386 (1937).
[2] Salt and Silica Deposits in Steam Turbines," by H. Goerke, *Elektrizitäts-wirtschaft*, 38 614–616 (1939).

as well as the compositions, expressed as per cent, upon evaporation to dryness, after subtracting sodium hydroxide, sodium chloride and sodium sulphate. Most of the chloride and sulphate found apparently came from the caustic soda used, inasmuch as it contained 0.2 per cent of sodium sulphate and 0.54 per cent of sodium chloride.

To date all six of the Windsor low-pressure units have been caustic-washed and the lost capacity restored. Two of these units were washed just prior to the annual overhaul, which permitted inspection of rotors and diaphragms. The buckets of one rotor still showed thin friable deposits near the roots and, in some stages, the buckets were covered with a thin powdery material which could be removed by wiping. Thin adherent deposits were still evident on some diaphragm nozzles. The other unit inspected showed the diaphragms and the buckets to be practically free of deposits.

It should be recognized that turbine deposits may unbalance the thrust forces sufficiently to throw an excessive load on the thrust bearing. Thus, in several instances, Windsor low-pressure-turbine deposits have made necessary the reduction of turbine output to limit thrust-bearing oil temperatures.

[The authors also related a similar experience and treatment with the low pressure turbine at Philo station and with boiler feed-pump turbines at Windsor—EDITOR.]

General Recommendations

Inasmuch as there has been comparatively little experience with the caustic washing of turbines, no specific recommendations can be made for a given application. Consideration of the turbine design and arrangement, together with further study of the washing procedure itself, must be the guide in its use. However, based upon the authors' experience to date, the following suggestions are offered for those who wish to attempt the removal of water-insoluble deposits from condensing units:

1 Since it is necessary, among other things, for the successful removal of deposits, to coat the affected surfaces with caustic soda, the method of introducing the solution should assure its thorough distribution over these surfaces. This is believed to be effectively accomplished by atomizing the solution and introducing it into the main steam flow.

2 The design of packing glands on turbine-stop and control valves should be carefully reviewed when the caustic-washing procedure is contemplated. Where the point of caustic-solution introduction is such as to permit the stem packing to be flooded with solution, some difficulty has been experienced with the sticking of stems and in removing the packing. This has occurred only on valves having stems which extend downward.

Consideration is being given to the use of a temporary soft packing during the washing operation, this packing to be replaced before the turbine is returned to service.

3 The foregoing precaution is also applicable to the more recent designs of packing glands which depend upon steam leak-off through close-clearance bushings. In one instance, some of the control-valve stems froze in the bushings and were extremely difficult to remove. Water-washing was ineffective in removing the solidified caustic. Depending upon turbine design, the proper selection of the caustic-solution injection point may forestall this difficulty.

4 For low-pressure units, the caustic solution usually can be most conveniently introduced by gravity flow. However, if advisable, it may be pumped.

5 During the caustic injections, the shell drains should be closed and, during the subsequent washing with condensate, these drains should be open to the condenser.

6 All turbine-instrument and bleed connections should be closed to prevent access of caustic to external equipment.

7 Excessive rates of temperature change of turbine parts should be avoided with the same care as used in normal operation.

8 The authors' experience with turbine deposits has been limited to those which are comparatively thin. To assure the removal of heavy deposits, it may be advantageous to repeat the entire washing cycle. As both physical and chemical characteristics of deposits are changed by caustic treatment, a unit so treated should not be returned to service before receiving a thorough water-wash. If a turbine is returned to service with heavy coatings treated by caustic, these coatings may become detached causing damage to the unit.

9 Although the authors have not used agents to improve the wetting properties of the caustic-soda solution, their use is contemplated in the near future. Such agents should be particularly effective where oily deposits exist on the latter stages.

Conclusions

Experience to date with seven low-pressure turbines and with three feed-pump turbines of the American Gas and Electric Company system indicates that the variety of water-insoluble turbine deposits encountered can be removed from turbine buckets and diaphragm nozzles by washing with caustic-soda solutions to regain lost capacity and to restore stage pressures to normal. This has been accomplished by using available connections as injection points and without definite knowledge of conditions for speediest and most complete removal of deposits. Studies are under way to determine, for specific types of deposits, the optimum conditions for their removal.

Although so far there have been only slight indications of water-insoluble deposits in our topping units, there is every reason to believe that these units or any high-pressure condensing units can be successfully washed, provided (1) facilities can be made available for introduction of the caustic solution at suitable points; (2) temperatures can be properly controlled; (3) wash water can be injected where it will remove soluble deposits and residual caustic effectively; and (4) the washings can be run to waste.

Fear has been expressed that the caustic soda may damage turbine parts, either from caustic embrittlement or corrosion. The authors grant that such conditions may occur but feel that the short period of caustic contact, the probable absence of high stresses if temperature conditions are properly controlled, and the thorough subsequent water-washing would make the likelihood of damage improbable. At the same time, they recognize that a thorough investigation to prove or disprove the possibility of such attack is highly desirable.

Slip Velocity in Boiler-Tube Circuits

By G. A. NOTHMANN* and R. C. BINDER†

This material is based on "An Analytical Study and Correlation of Data on Natural Circulation in Steam Boiler Tube Circuits" submitted by Mr. Nothmann as an M.S. thesis to Purdue University. It deals with the theoretical aspects of slip velocity and suggests means of incorporating its effect in a general analysis. Some experimental data on slip velocity are discussed and shown to be adequate only as a first approximation in an interpretation of velocity data. Further experimental investigations seem necessary before final conclusions can be drawn.

THE analysis of flow conditions for natural circulation in boiler-tube circuits has been carried out on the basis of various simplifying assumptions. The results found by theoretical analyses still deviate considerably from those observed under actual operating conditions, and it therefore seems desirable to make modifications in the analytical approach to the problem. This may be done by carefully analyzing some of the assumptions and simplifications made, and, wherever possible, introducing corrections for them. In the analysis of boiler circuits many investigators neglect the effect of the relative velocity of steam with respect to water, the so-called slip velocity. So far, however, no scientific data are available on the basis of which such a simplification might seem justified. It is the purpose of this paper to present a theoretical analysis of the effect of slip velocity and attempt to point out ways in which such an analysis may be incorporated in the general solution of natural circulation problems. In addition, it is shown why available circulation test data seem inadequate, and why further experimental investigations of the problem appear desirable.

Specific Weight Calculations

Slip velocity has an effect on the specific weight of a steam-water mixture circulating in a boiler circuit. This effect will therefore be discussed in detail first.

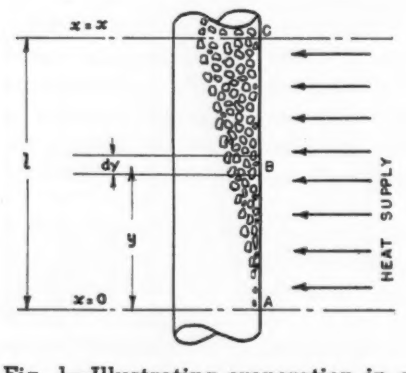

Fig. 1—Illustrating evaporation in a boiler tube

Evaporation in a boiler tube may be analyzed by reference to Fig. 1. It is considered to begin at point *A* and to end at point *C*. The quality of the mixture at the top, point *C*, has been termed the "top quality" and denoted by x. That at some point *B*, at distance y above *A*, is equal to

$$x_y = x\frac{y}{l} \qquad (1)$$

where l is the length of the evaporation section. This equation follows from the assumption of uniform heat supply from *A* to *C*. The specific volume at point *B* is then equal to

$$v_y = v_f + x_y(v_g - v_f) \qquad (2)$$

where v_g and v_f are the specific volumes of saturated steam and saturated water, respectively; the values of v_g and v_f are determined by the pressure at point *B*. The specific weight at point *B* then becomes

$$\gamma_y = \frac{1}{v_y} = \frac{1}{v_f + x_y(v_g - v_f)} \qquad (3)$$

An expression for the mean specific weight of a column such as that reaching from *A* to *C* in Fig. 1 was derived by Lewis and Robertson (9).[1] Neglecting the effect of slip velocity, they find the mean specific weight to be

$$\gamma = \frac{1}{x(v_g - v_f)}\log_e\frac{v_f + x(v_g - v_f)}{v_f} \qquad (4)$$

This expression shows that the mean specific weight of the column depends on the top quality x and on the specific volumes v_g and v_f which, in turn, are constant for any particular pressure. Fig. 2 shows the variation of mean and local specific weights of a steam-water mixture. The mean specific weight is the quantity given by equation (4), while the local specific weight is defined as the specific weight at the top of a column of top quality x; i.e., the specific weight of the mixture at point *C* in Fig. 1. These two quantities are plotted against top quality for various pressures. Logarithmic scales are used in order to magnify the conditions existing for low values of quality since most circulation problems fall within this region.

In the above analysis the effect of slip velocity was neglected. Slip velocity is defined by the equation

$$w_{sw} = w_s - w_w \qquad (5)$$

where w_{sw}, w_s and w_w are the slip velocity, the steam velocity and the water velocity, respectively. The effect of slip velocity on local and mean specific weight will now be analyzed, following to some extent the method of attack used by Seidel (4) and several other authors.

Let the quantities of water, steam and total mixture per unit of time flowing simultaneously through a cross-section of area, a, be W_w, W_s and W, respectively.[2] These quantities are related by the following equation:

$$W = W_s + W_w \qquad (6)$$

The defining equation of the mean specific weight γ at this section is

$$\gamma a = \gamma_s a_s + \gamma_w a_w \qquad (7)$$

where a_s and a_w are the portions of the total area occupied by steam and water, respectively, while γ, γ_s and γ_w represent the specific weights of the mixture, of the steam part, and of the water part, respectively. Since the areas a, a_s and a_w are related by the equation

$$a = a_s + a_w \qquad (8)$$

equation (7) may now be transformed either into

$$\gamma a = \gamma_s a_s + \gamma_w(a - a_s) \qquad (9)$$

or into

$$\gamma a = \gamma_s(a - a_w) + \gamma_w a_w \qquad (10)$$

from which result

$$a_s = \frac{a(\gamma - \gamma_w)}{(\gamma_s - \gamma_w)} \qquad (11)$$

and

$$a_w = \frac{a(\gamma - \gamma_w)}{(\gamma_w - \gamma_s)} \qquad (12)$$

The velocities of steam and water are given by

$$w_s = \frac{W_s}{a_s\gamma_s} \qquad (13)$$

and

$$w_w = \frac{W_w}{a_w\gamma_w} \qquad (14)$$

Substituting equations (11) and (12) into equations (13) and (14), respectively, renders

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[1] Numbers in parentheses refer to the bibliography at the end of this paper.

[2] W_w, W_s and W have the unit weight/time, as, for instance, pounds per second.

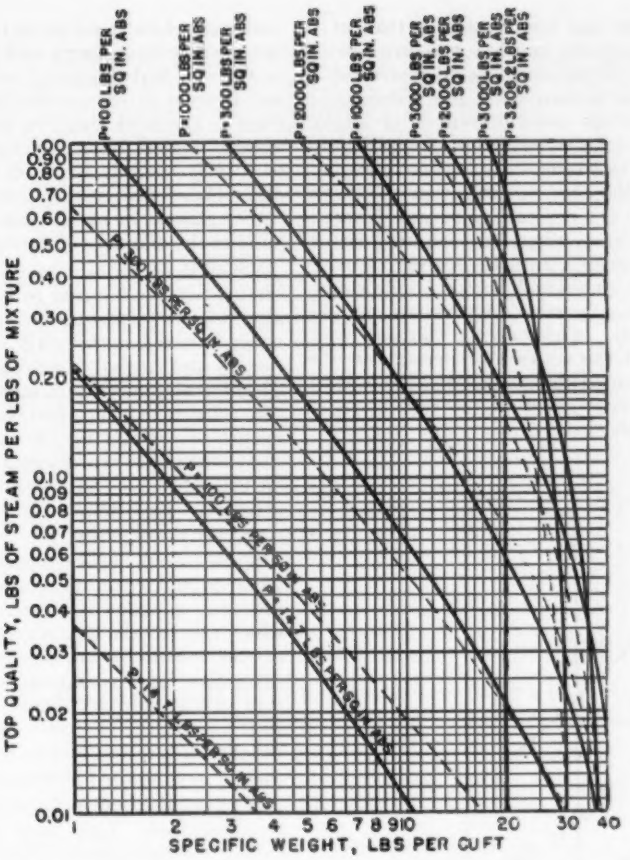

Fig. 2—Variation of mean and local specific weights of steam-water mixture; solid lines represent mean and broken lines local specific weights

$$w_s = \frac{W_s}{a\gamma_s}\frac{(\gamma_s - \gamma_w)}{(\gamma - \gamma_w)} \qquad (15)$$

and

$$w_w = \frac{W_w}{a\gamma_w}\frac{(\gamma_w - \gamma_s)}{(\gamma - \gamma_s)} \qquad (16)$$

Subtracting equation (16) from equation (15) results in

$$w_s - w_w = w_{sw} = \frac{W_s}{a\gamma_s}\frac{(\gamma_s - \gamma_w)}{(\gamma - \gamma_w)} - \frac{W_w}{a\gamma_w}\frac{(\gamma_w - \gamma_s)}{(\gamma - \gamma_s)}$$

$$= \frac{W_s}{a\gamma_s}\frac{(\gamma_s - \gamma_w)}{(\gamma - \gamma_w)} - \frac{(W - W_s)}{a\gamma_w}\frac{(\gamma_w - \gamma_s)}{(\gamma - \gamma_s)} \qquad (17)$$

and, introducing the top quality x for the ratio $\frac{W_s}{W}$,

$$w_{sw} = \frac{xW}{a\gamma_s}\frac{(\gamma_s - \gamma_w)}{(\gamma - \gamma_w)} - \frac{W(1 - x)}{a\gamma_w}\frac{(\gamma_w - \gamma_s)}{(\gamma - \gamma_s)} \qquad (18)$$

This equation may be rearranged, solved for the quality x, and, by substituting

$$W = aw_0\gamma_w \qquad (19)$$

where w_0 is defined as the velocity of an equivalent saturated water column, transformed into

$$x = \frac{\dfrac{w_{sw}}{w_0} + \dfrac{(\gamma_w - \gamma_s)}{(\gamma - \gamma_s)}}{\dfrac{\gamma_w}{\gamma_s}\dfrac{(\gamma_s - \gamma_w)}{(\gamma - \gamma_w)} + \dfrac{(\gamma_w - \gamma_s)}{(\gamma - \gamma_s)}} \qquad (20)$$

The ratio w_{sw}/w_0 may be replaced by the symbol σ, and the final result becomes

$$x = \frac{1 + \sigma\dfrac{(\gamma - \gamma_s)}{(\gamma_w - \gamma_s)}}{1 - \dfrac{\gamma_w}{\gamma_s}\dfrac{(\gamma - \gamma_s)}{(\gamma - \gamma_w)}} \qquad (21)$$

It should be noted that if, in equation (21), the value of σ becomes zero, i.e., if the slip velocity is zero, the equation simplifies into

$$x = \frac{1}{1 - \dfrac{\gamma_w}{\gamma_s}\dfrac{(\gamma - \gamma_s)}{(\gamma - \gamma_w)}} \qquad (22)$$

which, after rearranging and solving for γ, reduces to equation (3).

Although equation (21) contains the quality x explicitly and the specific weight γ implicitly, it may be interpreted in terms of γ as follows: The specific weight of the mixture at any point is a function of the quality x, of the quantities v_f and v_g, which are constant for any given pressure, and of the ratio σ of the slip velocity of steam with respect to water w_{sw} divided by the equivalent water velocity w_0. It will be shown that, at present, the data available with respect to the actual magnitude of the relative velocity w_{sw} or the ratio σ are very incomplete. In view of this fact, successive values of σ were assumed, ranging from

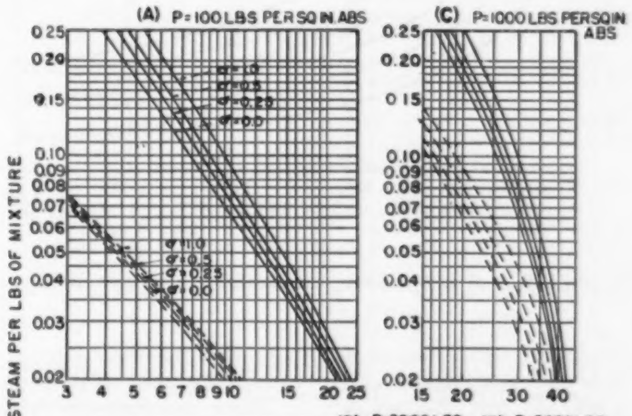

Fig. 3—Curves for local and mean specific weights, slip velocity considered; solid lines represent mean and broken lines local specific weights

0.0 to 1.0, and corresponding values of γ were calculated. This may be done with greater ease by plotting curves according to equation (21) with x as a function of γ rather than by solving this equation for γ.

Curves for local specific weight against local quality may be plotted and integrated graphically to determine the mean value of the specific weight of the column. The curves for local and mean specific weights thus determined are shown in Fig. 3. These curves correspond to those of Fig. 2, and the curves for $\sigma = 0$ are identical with the latter. As shown in Fig. 3(A), the four curves are drawn for values of σ equal to 0.0, 0.25, 0.5 and 1.0, reading from left to right in every family of curves. The same order applies to the corresponding curves in Figs. 3(B), (C), (D) and (E). By use of these curves it becomes comparatively simple to find the specific weight of a circulating steam-water mixture for any given top quality and pressure. The effect of slip velocity on specific weight may amount to as much as 25 per cent. Since this effect is always of such a nature that it raises the specific weight of the mixture, it lowers the so-called available pressure difference (which is a function of the difference in specific weight between the water and the mixture columns) bringing about circulation.

Fig. 4 shows the effect of slip velocity on the available pressure difference, based on the assumption that the mixture circulates in a U-tube circuit in which the downcomer contains water only while the riser contains a mixture of quality varying uniformly from 0 at the bottom to x at the top. These curves indicate clearly that the reduction in available pressure difference due to slip velocity is greater at low top qualities and high pressures than at high top qualities and low pressures, respectively. It should be noted that these curves do not in themselves give a definite clue as to the eventual effect of slip velocity on the velocity of circulation. This latter effect can only be determined by a simultaneous investigation of the variation in the resistance pressure drops (due to entrance, kinetic, accelerating and friction losses (9)), an investigation which depends on individual circuit conditions and can be only very approximate on a general basis. This may be clarified by stating that the velocity of circulation is found by setting the available static pressure difference[3] equal to the sum of resistance pressure drops. However, a complete discussion of this is contained in the bibliography reference noted.

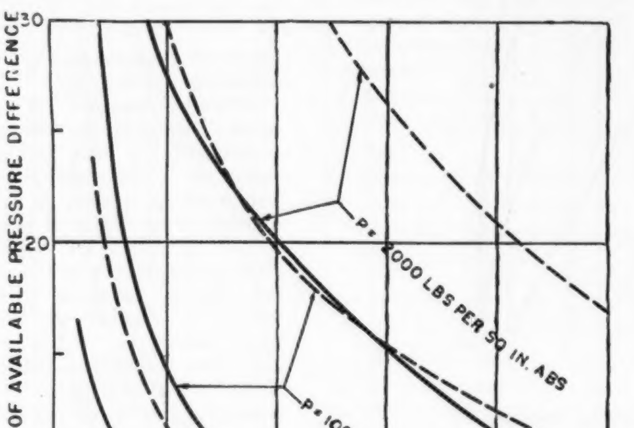

Fig. 4—Effect of slip velocity on available pressure difference

From this discussion it should not be inferred that the value of $\sigma = 1.0$ is necessarily a maximum. This question cannot be decided until more data concerning slip velocities are available. It is believed, however, that the range of values covered, i.e., from $\sigma = 0.0$ to $\sigma = 1.0$, includes the majority of cases occurring in practical problems. This belief is based on the values of slip velocity reported so far. These are reproduced in Fig. 5 and may be considered as giving a fair indication at least as far as the order of magnitude of slip velocities is concerned.

Magnitude of Slip Velocity

An accurate determination of the magnitude of slip velocity is not possible on the basis of data available to date. At the same time, Lewis and Robertson (9) point out that the slip velocity may be negligible in the so-called slug stage of evaporation and to some extent also in the water film stage. The froth stage, in which the slip velocity might be considerable, is comparatively short in common U-tube boilers. These statements, however, are rather general in nature and become less valid as the diameter of the tube increases.

Schmidt, Behringer and Schurig (6) carried out experiments to determine the slip velocity of steam evaporated from water in tubes, both for the case of a stationary and for that of a circulating liquid. They found that, for a stationary liquid, the slip velocity depends, first, on the specific weight of the mixture, a variable which was measured experimentally; second, on the tube diameter; and third, on the pressure. The results found by Behringer are shown in Fig. 5.[4]

Since the slip velocity itself affects the value of the mean specific weight of the mixture, as shown above, calculations which are to take into account the effect of slip velocity must be carried out by successive approximations. The variation of the terms involved is generally small and the second approximation usually leads to an accurate result. Fig. 5 may be used in the following manner:

A reasonable value of specific weight is first assumed. This may be done by taking the value found from Fig. 2 with slip velocity neglected. A vertical line at the corresponding abscissa in Fig. 5 is extended to the curve corresponding to the appropriate pressure. A horizontal line drawn through the new point thus found is extended to the line designating the diameter of the tube. The value of slip velocity is found vertically below this latter point of intersection. This procedure is indicated in Fig. 5 for the case of $\gamma = 31.6$ lb per cu ft, $P = 294$ lb per sq in. abs, and $d = 3^1/_2$ in., resulting in a slip velocity w_{sw} of 3.7 ft per sec. On the basis of the corresponding value of $\sigma = w_{sw}/w_0$, a new value of specific weight is found from curves as given in Fig. 3, and the process is repeated until the desired degree of accuracy is attained. It is seen that a higher specific weight of the mixture, a higher pressure or a lower diameter will have the effect of decreasing the slip velocity, and vice versa.

The results found by Behringer, accurate though they may be for the conditions existing in the experimental apparatus used by him, are not necessarily applicable to circulation problems in general. The reason for this fact is based mainly on two factors involved in the Behringer experiments. In his apparatus, heat was applied only at the bottom of the tube. Further investigation must determine whether Behringer's results can be reproduced with reasonable accuracy if heat is supplied uniformly along the whole

[3] Available static pressure difference is defined as height of circuit × ($\gamma_{downcomer} - \gamma_{riser}$).

[4] For low and medium pressures, and to some extent, for high pressures and low specific weights, slip velocity increases with tube diameter. Beyond a certain limit, corresponding to a slip velocity of about 1.8 ft per sec in Fig. 5, this relationship apparently reverses, and the lines for various tube diameters intersect at this point. Inasmuch as Behringer's tests were not carried beyond this limit to any great extent, Fig. 5 was limited to the region above and to the left of this point of intersection.

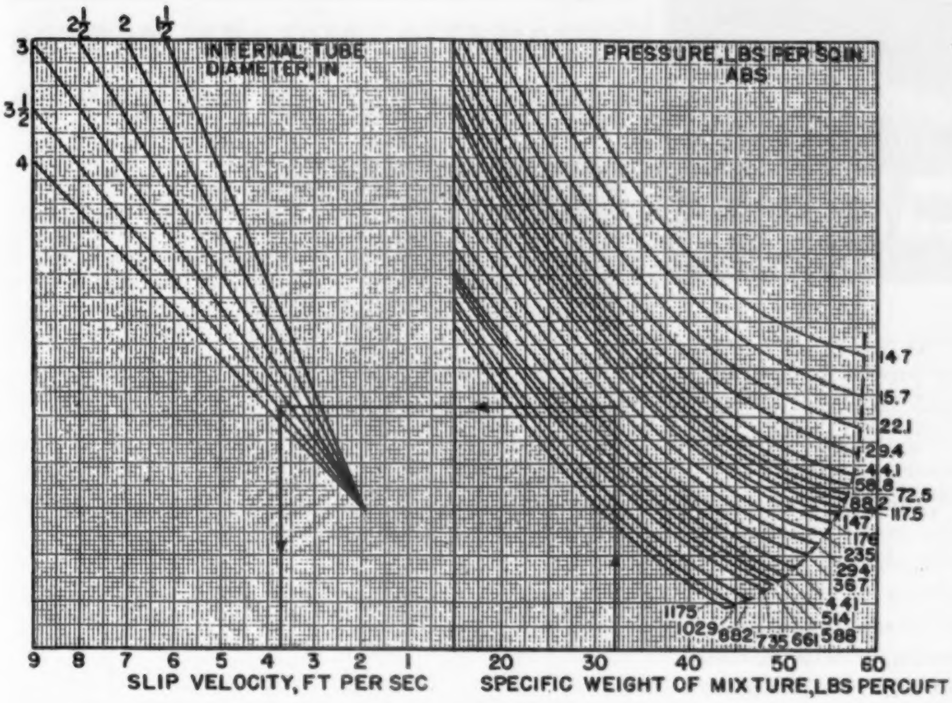

Fig. 5—Plot of Behringer results

specific weight can be taken into account on a theoretical basis. (2) Slip velocity is conveniently taken into account by the use of a dimensionless ratio σ, defined as the ratio of slip velocity to equivalent water velocity in the tube. (3) Graphs are presented showing the effect of several values of σ, ranging from 0.0 to 1.0, on the specific weight of a steam-water mixture in a tube. The variation of specific weight, as a result of slip velocity, is found to be as great as 25 per cent for high values of σ. (4) It is found that the experimental data on slip velocity reported thus far on the basis of model tests are insufficient. The reason lies partly in the fact that some authors report only a very small number of detailed results and partly in the lack of dynamic similarity of the models used. As yet no final conclusions can, therefore, be drawn as to the actual magnitudes of slip velocity in boiler tubes.

column of the steam-water mixture, an arrangement which would approximate actual conditions more closely. The second and more important factor, however, lies in the fact that slip velocity also depends on the absolute velocity of the liquid. It was found by Schurig that, if steam is evaporated in a stationary liquid and bubbles rise with some velocity w_1, the corresponding bubble velocity of steam evaporated in a column moving with a velocity equal to w_2 will not necessarily, as might be expected, be equal to $(w_1 + w_2)$. This result is all the more important inasmuch as a theoretical derivation for slip velocity becomes extremely complex, if not impossible, where it is to take into account the effect of the absolute velocity of the liquid which is evaporated. Schurig carried out experiments designed especially to investigate this part of the problem. His results are shown in Fig. 6. The data given do not permit any exact quantitative evaluation. They indicate very clearly, however, that the effect of the liquid velocity may be quite considerable.

E. Schmidt, in his introduction to Schurig's paper, states that it is almost impossible to give the reason why the slip velocity should depend on the velocity of the liquid as such; until further experimental data are available, it is difficult to analyze these velocity conditions with any degree of accuracy. Fig. 5 is given as an example of how slip velocity may be plotted on the basis of experimental data. Whenever no accurate data on a certain phenomenon are available, one chooses the best so far obtained which, the authors believe, are given by the work of Behringer. At the same time, the fact that slip velocity data as yet are to some extent insufficient is supposed to be one of the points under discussion, and the probable inadequacy of the chart in Fig. 5 serves to amplify this point.

It is believed that the use of photometric and electronic instruments in circulation tests should simplify greatly an accurate analysis of the conditions existing. The application of photographic, stroboscopic and cinematographic measurements to evaporation tests is illustrated by M. Jakob (8) for the case of water evaporating in glass jars.

Conclusions

The effect of slip velocity on circulation in boiler tubes is analyzed in detail and the important results found are as follows: (1) If data on the actual value of slip velocity are available, its effect on

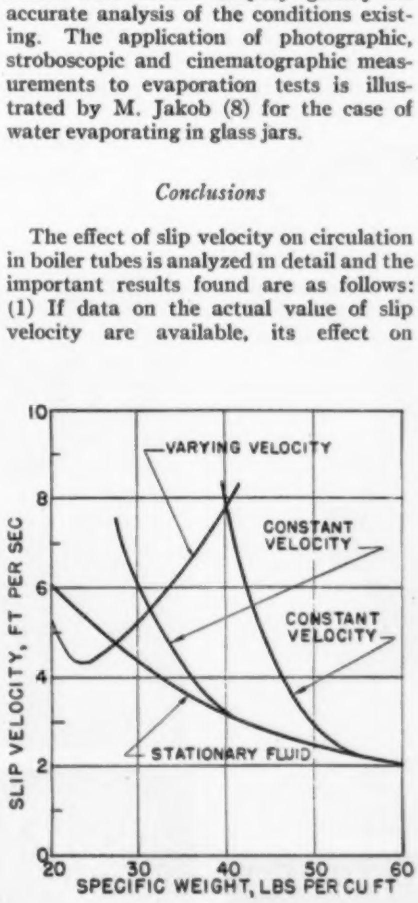

Fig. 6—Plot of Schurig results

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* Titles translated by the author.

Smoke Prevention Association Holds Annual Meeting at Pittsburgh

AMONG the principal topics discussed during the three-day Annual Convention of the Smoke Prevention Association at Pittsburgh, June 8 to 11, were the collection and analysis of fly ash, the smoking tendencies of various coals, overfire air, control of railroad smoke and problems incident to the many conversions from oil to coal.

At the opening luncheon session, following addresses by President Arthur E. Hutchinson, Mayor Scully and other civic leaders, representatives of the petroleum industry cautioned against any expectations of improvement in the fuel oil situation and predicted that increased military needs would make necessary the extension of gasoline and fuel oil rationing to areas as far west as the Mississippi.

Three papers were presented at the first technical session on Wednesday morning. These were, "The Chances of Error in Sampling Coal," by H. F. Hebley of the Pittsburgh Coal Company; "Smoke Tendencies in Coals of Various Ranks," by Dr. H. J. Rose of Mellon Institute of Industrial Research; and "Smoke as Seen Through the Eyes of a Chemist," by Dr. E. Berl of Carnegie Institute of Technology.

Recalling that it takes $11^1/_2$ man-hours to work down a sample of coal according to the standard prescribed by the Bureau of Mines, Mr. Hebley advocated for practical commercial sampling a simple procedure in which the sample is crushed in one operation to $^3/_{16}$-in. size and then put through a riffle. The errors involved in reduction by this means, he believed to be less than those incident to collection of the sample. He cautioned against placing too much importance on individual samples and showed, by means of charts, that the average of many samples taken by the coal producer is a better guide.

Commenting upon the common practice of dividing a gross sample into three bottles, two of which are used for check analysis and the third for reference in case of disagreement, Mr. Hebley pointed out that this resolved merely into checking the accuracy of the laboratory testing, and that too often the greatest weight seemed to be given the analysis of the third sample. He made a plea for new A.S.T.M. sampling procedure that would not be invested with too much rigidity.

Tar Responsible for Smoke

Doctor Rose reviewed the widely accepted classification of coal by rank and pointed out that the lower rank coals are based on heating value, while those of higher rank are classed according to their carbon content. As to smoking tendencies, anthracite with 2 to 8 per cent volatile, which contains no tar and the volatile of which is mostly hydrogen, is inherently smokeless. Semi-anthracite, with more than 8 per cent volatile, is substantially smokeless, although its small tar content under certain conditions may give a slight trace of smoke and its burning is usually accompanied by a detectable odor. From 5 to 12 per cent of the heat given up by anthracite may be credited to the volatile.

Coming to the bituminous coals, the speaker showed that the tar content increases almost directly with the volatile. The tar in low-volatile coals will range from 30 to 120 lb per ton; that in medium volatile coals up to 200 lb per ton; and for high-volatile coals as much as 300 to 350 lb per ton, which is equivalent to a barrel of tar per ton of coal. Nearly half the heat in such coals is contained in the volatile matter. There is likely to be less of a smoke problem with low-rank coals, such as the mid-continent variety, because the tar yield is less. Low rank coals are generally free burning but those in the middle group with high tar content usually have caking characteristics.

Discussing the chemical aspects of smoke, Dr. Berl pointed out that the well-known London fog is caused by condensation of moisture on smoke particles. In fact, New York City which largely burns anthracite and is generally regarded as a smokeless city occasionally has fogs caused by the condensation of water vapor on the dust particles which fill the air. The speaker pointed out that velocity due to molecular impact of smoke particles is greater than that due to gravitation, hence the tendency of the finer particles to settle at a considerable distance from the point of emission. Winds are also a factor.

Dr. Berl further discussed the production of smoke and fumes from various chemicals for military purposes.

Collection and Analysis of Fly Ash

"The Collection and Disposal of Fly Ash from Spreader Stokers" was the subject of a paper at the second session by K. H. Bowman of Dravo Corporation. Inasmuch as the fly ash in such cases may consist of as much as 40 to 60 per cent combustible, the speaker stressed the necessity of ample furnace volume to permit time for burning, the importance of over-fire air to increase turbulence, and automatic control. He described a type of mechanical arrestor which his organization had found effective. This consists of a helicoid inserted in a cylinder having slots which is placed in the stack. The helicoid produces a whirling motion to the stack gases and the fly ash is thrown out through the vertical slots in the cylinder and drops down into a hopper. All the coarse and some of the fine particles are thus removed. Because the velocity is low, the draft loss, through the spiral, is low, not over $^1/_{10}$ in., and an induced-draft fan is necessary only if the stack is short.

Mr. Bowman advocated the re-injection of recovered fly ash into the furnace, but this should be done while the boiler is under heavy load rather than at light load. Answering a question as to the advisability of injecting the fly ash where it might strike the hot bridge-wall, he replied that if the bridge-wall is not high enough to cut down reflected heat, clinker may be formed.

"The Analysis of Fly Ash" was discussed by H. C. Dohrman, Chief Engineer of Buell Engineering Company, who showed that for the measurement of particles of dust below 43 microns it becomes necessary to resort to the elutriation or sedimentation methods. After describing the Andreasen Sedimentation Apparatus and pointing out certain limitations due to the influence of surface particles, he proceeded to describe in detail the Buell Elutriator which yields results in terms of terminal velocity which, in turn, is translated into equivalent particle size by means of Stokes Law. In describing the sampling methods he cautioned that the nozzle velocity must be the same as that in the duct in order to get a representative sample. The accuracy of sampling across a large duct he believed to be within 2 per cent, but this did not mean that the dust concentration would be uniform across the duct.

Smoke Surveys

Reporting on the results of "Surveys of Heating and Power Plants in Various Cities With Recommendations for Smoke Elimination," C. F. Hardy of the Coal Producers' Committee for Smoke Abatement, told of some 600 plants visited, only 2 per cent of which were in first-class condition and well operated. These, for the greater part, were small installations, many hand-fired and supplying steam for heating or power for relatively small industrials. The biggest smoke offenders were the hand-fired plants whose firemen had various other duties besides attending to the boilers. Poor draft conditions were common; nearly 60 per cent of the plants visited had leaks in the breeching or settings; in many of the stoker-fired plants there was lack of turbulence of the gases; and a practice all too prevalent was that of shoveling coal on top of the stoker fuel bed and barring, in order to meet increased load. This is productive of smoke.

Mr. Hardy remarked that what makes locomotive smoke most objectionable is that it is discharged close to the ground and may be spread from one end of a town to the other. He believed that if a spreader stoker is equipped with fly-ash recovery and automatic (not on-and-off) control that objectionable stack discharge or smoke need not result.

Overfire Air

Difficulty in obtaining priorities on fans under present conditions led to an investigation of steam jets at Battelle Memorial Institute which was reported in a paper by R. B. Engdahl of that institution. Among the variables studied were the diameters of

the steam nozzle and air tube, the length of the air tube, its shape, the location of the nozzle and the steam pressure.

There appeared to be no optimum size of steam nozzle for maximum efficiency, but the best location for the steam nozzle appeared to be one air-tube diameter from the throat of the latter. The optimum length of air tube appeared to be about $7^1/_2$ diameters and a well-rounded entrance gave best results. Moreover, a straight tube was better than a venturi and a plain orifice outlet on the nozzle seemed preferable. Within the pressure range investigated, namely, 50 to 175 lb per sq in., the higher the pressure the greater the air delivery, with a slight dropping off in efficiency.

To be effective, the velocity of the air must be 1000 ft per min or more and the penetration of the steam jet alone was found to be about 10 per cent less than with steam and air. Such was also the case with air alone when supplied by a fan.

A common objection to employment of a steam jet is the noise. To obviate this to a very great extent, a silencing box lined with rock wool had been devised and was described in the paper.

A timely paper on "Overfire Air Performance Applied to Stationary Plants" was presented by Harry Carroll of the Commercial Testing & Engineering Company. "The many conversions from oil to coal and inability of numerous plants to get the coal best suited to their needs offers a wide field for use of overfire air," he said. Cautioning against the assumption that many of these conversions are temporary, he urged that such changes be made on a permanent basis, or at least for such a period as will return the cost in savings.

Owing to existing settings and furnace volumes it is not always possible to have conversions conform to smoke requirements and here is where the use of air jets will help. While overfire air supplied by fans is desirable for large installations, the steam jet has a place in the smaller unit. The jet should be made of material that will resist wear with moist steam and be so designed as to avoid excessive use of steam. Also, direct impingement on brickwork should be avoided. However, some of the steam thus used is offset by improved operating conditions and cleaner surfaces.

Mr. Carroll showed slides of a number of typical installations of various sizes and types, including those fired by single-retort-, multiple-retort and chain-grate stokers.

Railroad Smoke

The Thursday afternoon session was devoted to two papers on railroad smoke. In the first of these, W. H. Kimberly, Smoke Inspector of Pittsburgh, told of the close cooperation on the part of all the railroads entering that city, of their system of having company smoke inspectors and the close check that the latter maintain against not only violations but any smoke not serious enough to constitute a violation.

The second paper, by Samuel A. Dickson, Supervisor of Fuel Economy for the Chicago & Alton Railway, discussed "Throttle and Reverse Lever Control as an Influence on Smoke Abatement." In this he showed that avoidance of smoke is a matter that concerns the locomotive engineer in his handling of the throttle and cutoff even more than the fireman. The paper brought forth extensive discussion from the floor.

At the annual banquet held on Thursday evening, Dr. A. A. Bates of the Westinghouse Research Laboratories gave an interesting talk on "Materials of the Future."

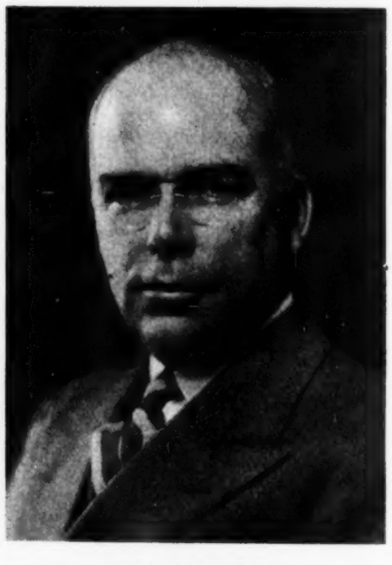
A.S.M.E. Nominations

Reporting at the Semi-Annual Meeting of the American Society of Mechanical Engineers in Los Angeles, June 14–17, the Nominating Committee submitted the following slate of officers of the Society for the year beginning next December.

President: Robert M. Gates, President of The Air Preheater Corp., New York.

Vice-Presidents: R. F. Gagg, Asst. to Gen. Mgr. of the Wright Aeronautical Corporation; D. W. R. Morgan, Westinghouse Electric & Mfg. Co; J. A. Noyes, Sullivan Machinery Co., Dallas, Texas.

Managers: A. C. Chick, Asst. Vice-President, Mfrs. Mutual Fire Ins. Co., Providence, R. I; S. H. Graf, Prof. of Mech. Engrg., Oregon State College; J. M. Robert, Dean of Engineering, Tulane Univ., New Orleans, La.



Robert M. Gates

Mr. Gates is a graduate of Purdue University and after several years in the materials handling field, and as a consulting engineer, joined The Superheater Company of which he subsequently became Vice-President. From 1933 to 1939 he was also Vice-President of Combustion Engineering Company and was then elected President of The Air Preheater Corporation which position he now holds. He has long been active in the A.S.M.E., serving on many important committees, also as a Manager and a Vice-President of the Society, and has more lately been actively identified with the numerous production clinics sponsored by the Society in various war production centers.

Readjusted Power Contracts Effect Large Savings

Vice Chairman Basil Manly of the Federal Power Commission, speaking before a conference, sponsored by the War Department in Chicago on June 4, said that Federal procurement agencies to date have submitted contracts for review involving an estimated demand of 5,375,000 kw, an annual consumption of 37,500,000,000 kwhr and annual charges of 225 million dollars. By presidential directive the Commission is charged with reviewing these contracts for electric energy and gas. Of a total of 664 war power contracts, 411 have been executed and subject to renegotiations.

To date, readjustments in rates acceptable to the utilities have resulted in annual savings of $1,560,000, and those in facility charges to $1,983,000. Mr. Manly pointed out that most of these contracts for power and gas were originally negotiated under stress and that it is no reflection on any of the parties participating in the negotiations that rate adjustments and other modifications were found necessary or desirable. In fact, prior to the President's directive, voluntary readjustment had been made between several government agencies and the utilities which effected annual savings of $446,900 for electricity and gas; and $1,074,000 in connection and facility charges.

Personals

A. W. Thorson, Assistant to the President of Carnegie Institute of Technology, is temporarily associated with the Office of Solid Fuels Administration in Washington, D. C.

V. H. Peterson, for the past two years Vice-President of the Elliott Company, has been appointed Assistant to the President of The Baldwin Locomotive Works.

Roland R. Ware, for the past thirteen years General Manager of the Clarage Fan Company, has been elected President of that company. He succeeds **Harry Clarage** who was named Chairman of the Board.

Henry A. Christy, formerly Superintendent, has been made Works Manager of The C. O. Bartlett & Snow Company, Cleveland, succeeding **C. J. Neville,** now Vice-President and Treasurer.

Passing of Joseph W. Hays

Joseph Weller Hays, founder of what is now The Hays Corporation, died at the family home in Grinnell, Iowa, on April 22 at the age of 75. A practical operating engineer, consultant, writer, lecturer, inventor and teacher, he touched intimately the lives of thousands in the steam plants of the nation.

Born in Chester Township, Paweshiek County, Iowa, in 1868, Joe Hays attended the nearby country school and later Grinnell College Academy and Cornell College at Mt. Vernon, Iowa, from which he graduated with a literary degree in 1890. In 1893, while visiting the World's Columbian Exposition in Chicago, he was impressed by the pall of smoke that enveloped the city, and his desire to do something about it caused him to abandon a career in journalism for one in combustion.

His absorbing interest in smoke abatement and combustion efficiency and his inventive mind soon produced fuel savers and waste detectors in many forms. Among the first was an improved portable flue gas analyzer. Later came a CO_2 recorder for which Mr. Hays and his brother Charles were awarded a Certificate of Merit by the Franklin Institute of Philadelphia.

In 1918 Mr. Hays moved from Chicago to Michigan City where, besides acting as consultant on combustion problems, he conducted a very successful instrument business known as The Joseph W. Hays Corporation. In 1925 Mr. Hays disposed of this business to Phil. T. Sprague and it was known thereafter as The Hays Corporation. Free to devote his time to consulting work and writing, he rewrote his well-known book, "How to Build Up Furnace Efficiency," adding to it from his growing experience. He also wrote the Hays Correspondence Course in Combustion Efficiency which is still being offered by The Hays Institute of Chicago.

As a pioneer in combustion efficiency, and the first man to be known as a "combustion engineer," probably no man in America was so well known to boiler room operators and thousands of others in industry as Joe Hays. His book, now in its 18th edition, will perpetuate his name.

Production Awards

The Navy Board for Production Awards has granted a renewal of the Navy "E" Award made in May 1942 to the De Laval Steam Turbine Company, for excellence in industrial production. The new award is made for a period of six months, dating from November 15, 1942, and carries the right to add a White Star to the Navy "E" Burgee flown over the plant.

The U. S. Maritime Commission's Maritime "M" Pennant, Victoria Fleet Flag and Labor Merit Badges were presented by Commissioner Thomas M. Woodward recently to the employees of The Edward Valve & Mfg. Company. W. F. Crawford, President of the Company, accepted the "M" Pennant and James C. Benson, veteran mechanical inspector, accepted the labor merit insignia on behalf of the employees.

The Ridgeway Plant of the Elliott Company has been presented with the Army-Navy "E" by Commander R. G. Walling, U.S.Navy. Howard M. Hubbard, President of the Elliott Company, accepted the pennant on behalf of the company and its workers. Lt. Col. Thomas H. Eddy presented Army-Navy "E" pins for the employees which were accepted on their behalf by veteran employee C. A. Josephson, President of the plant local of the U.S.W.A.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

1943 A.S.T.M. Symposium on Radiography

This 265-page book issued by the American Society for Testing Materials includes 18 technical papers presented by outstanding authorities. The major part of the book includes the technical contributions in the 1942 Symposium, but an important part is the collection of 1936 papers, several of which have been extensively revised, some condensed. The Symposium has as its basic purpose the development of better understanding of radiographic tests and their significance on the part of both the consumers and producers of materials.

There are extensive contributions on principles of radiography; foundry applications; miscellaneous applications; gamma-ray radiography with instructions for using radium; and the problem of inspection. Other topics covered include applications to production problems; welds and weldments; magnesium aircraft castings; correlation of mechanical properties and radiographic appearance of magnesium alloy castings; million-volt portable unit; high-voltage X-rays in the boiler shop; welded high-pressure power plant piping; apparatus used in radium radiography; exposure meter; study of cassette design; precision radiography; X-ray film evaluation; industrial X-ray protection; and recommended A.S.T.M. industrial radiographic terminology.

Special coated stock has been used to bring out the some 175 illustrations used in the book. Bound in maroon cloth, size 6 × 9. Price $4.00.

Marine Engineering

By J. M. Labberton

The current expanded program of both naval and merchant shipbuilding has been accompanied by an almost insatiable demand for engineering talent, and many engineers with mechanical and electrical schooling have been attracted to the marine field. These engineers generally find the applications of their talents familiar, but the new background is strange. To such, this volume will prove an easily understood handbook—a sort of "refresher."

Professor Labberton has written an excellent treatise to fill a widespread need. His presentation is concise and in language the practising engineer will readily comprehend and appreciate. The author's intimate knowledge of his subject and of the needs of engineers is everywhere evident throughout the book. The text is copiously illustrated and the selection of illustrations is excellent, indicating that much thought was given to this phase of the book. The cases worked out in detail for actual equipment selection and the data included in tables and charts will be found quite helpful.

With chapters on Hull Design and Resistance, Propellers, Propulsion Shafting, Reduction Gears, Marine Fuels and Combustion, Boilers or Steam Generators, Turbines, Marine Pumps, Heat Exchangers, Forced Draft and Ductwork, Marine Electrical Engineering, Refrigeration, Feed Systems, Heat Balance, The Diesel Ship, Layout, Astern Operation, Electric Drive, Naval Vessels, and Ship's Trials, the field is covered thoroughly. The engineer newly come to the marine field should find the answers to many of his problems in this fine volume.

The book contains 439 pages size, $6^1/_4 \times 9^1/_4$, bound in dark green buckram. Price $4.00.

Mathematics Dictionary (Revised Edition)

By Glen James and Robert C. James

This invaluable reference book, which first appeared in 1942, is designed to provide a condensed source of facts and principles for men working in practical fields where mathematics is an essential feature. In this revised edition, many new terms have been added, more "working examples" have been introduced, irregular plurals added, typographical errors corrected, five place logarithm tables have been substituted for four place tables and extensive integral tables have also been added. Elementary concepts and definitions have been simplified for the benefit of the layman, but basic terms beyond calculus have been included so that the dictionary contains most of the terms which form the foundation of any advanced course in mathematics.

The *Mathematics Dictionary* contains 320 pages, size $6^1/_2 \times 9^1/_4$, and is available in either flexible or non-flexible blue fabrikoid binding. Price $3.00.

Modern Marine Engineer's Manual—Volume II

Alan Osbourne, Editor-in-Chief

More than a year has passed since the first volume of the Modern Marine Engineer's Manual was published. Volume II now supplements the material in Volume I concerning propulsion machinery on board turbine and reciprocating engine vessels by a similar comprehensive handling of Marine Diesel Engines by J. F. Hecking, which in itself, comprises 263 pages and includes 116 illustrations.

Ten other sections round out the coverage of subjects not dealt with in the previous volume. These include: Modern Marine Refrigeration, by Earl S. Shulters; Heating, by John H. Clarke; Ventilation, by John W. Markert; a short section on Insulation; Steering Gear and Deck Machinery, by Frank C. Messaros; and Modern Marine Electricity, by P. de W. Smith. There are also shorter sections on Propellers and Propulsion, by Alan Osbourne; Instruments, and Tables, by Alan Osbourne and W. H. Robinson; and some condensed notes on Tests and Trials. John C. Martin is also listed as a contributing editor.

The text is written in a simple direct style and is illustrated with hundreds of line cuts and halftones. The book, which includes a 35-page index, comprises 1200 pages, size $5 \times 7^1/_4$, and is bound in dark blue buckram. Price $4.00.

The Proceedings of the 3rd Annual Water Conference of the Engineers' Society of Western Pennsylvania

The Proceedings of the 3rd Annual Water Conference, held at the Hotel William Penn on November 9 and 10, 1942, are now published and, among the nine papers presented, two are of particular interest to power plant engineers. These are: "Solubility of Salts in Steam at High Pressure" by Frederick G. Straub, Research Professor of Chemical Engineering at the University of Illinois, and "Protection Against Caustic Embrittlement by Coordinated Phosphate pH Control" by Dr. S. F. Whirl (Chief Chemist) and T. E. Purcell (Gen. Supt. of Power Stations) of the Duquesne Light Company. Other papers pertain to water treatment, slime control, underwater paints or other specialized equipment. Price $3.00 per copy, plus postage.

Questions and Answers for Marine Engineers, Books VII and VIII

Compiled by Captain H. C. Dinger, U.S.N. (Retired)

These two volumes—*Book VII—Diesel Engines, Electrical Equipment,* and *Book VIII—Materials and Calculations, Handy Tables*—complete the series of Question and Answer booklets which first appeared in the pages of "Marine Engineering and Shipping Review."

Much practical information on the operation and maintenance of diesel engines is given in the eight chapters comprising Part I of Book VII. Answers to questions on the operation of electrical equipment which the chief engineer on a small diesel ship is often called upon to operate, is given in Part II of the same volume.

In Book VIII are collected the questions relating to strength and other calculations, also the properties and treatment of steel and other materials, including chapters on Welding and Annealing, X-ray and Special Treatments, and Protective Coatings for Metal. The concluding chapter gives useful tables and information that should be helpful in solving problems met with in the day's work.

The questions and answers contained in any of the booklets in this series can be studied with profit by men preparing for license examinations.

Books VII and VIII contain 130 and 159 pages, respectively. Bound in paper covers, size $5 \times 8^1/_2$. Price $1.00 each.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

American Standards

The American Standards Association has issued its List of American Standards for 1943. Standards are listed by subject and cover civil, mechanical, electrical, mining, chemical and other fields. More than 600 standards are listed, 94 of which represent new and revised standards approved since the last (August 1942) issue. This 20-page bulletin will serve as a useful reference piece to the engineering and purchasing departments of manufacturing firms.

Axial Flow Blowers

The L. J. Wing Manufacturing Company has issued an 8-page bulletin (CO-5) featuring its line of axial flow blowers. Capacities run as high as 50,000 cfm and static pressures as high as 12 in. The application of the blower to different methods of firing and different types of boilers is illustrated in many installation views.

Boiler Water Conditioning

The Elgin Softener Corporation has issued a 16-page bulletin (504) which explains the types of impurities found in boiler feedwater, the common causes of sludge, scale, corrosion and carryover, and how to prevent these troubles by the use of Elgin deconcentrator systems. The bulletin is well illustrated with photographic halftones and diagrams.

Emergency War Agencies

The Office of War Information has issued a 144-page guide to the federal agencies devoted to the prosecution of the War entitled "Handbook of Emergency War Agencies." The handbook includes organizational outlines and the names and addresses of officials of emergency war agencies, the War and Navy departments and the United States Maritime Commission. It is designed to help the public reach the services it needs within these agencies. Copies of the handbook may be obtained by writing to Superintendent of Documents, Government Printing Office, Washington, D. C. Price 20 cents each.

Index to A.S.T.M. Standards

The "Index to A.S.T.M. Standards, Including Tentative Standards" is really an adjunct to the society's 1942 Book of Standards, and furnishes a ready reference to locating any one of some 1100 standards, specifications and tests in the volumes. The Index is also of service in determining whether A.S.T.M. has issued standard specifications, test methods or definitions covering a particular engineering material or subject.

Refractory Insulation

In a recent 4-page folder, Quigley Panel Constructions, Inc., announced a new high-temperature refractory insulation known as "Lightweight Insulblox." The insulation is available in blocks, pipe covering and pipe covering segments, and is recommended to withstand temperatures up to 1600 F. Many other refractory products are described in a binder collection of bulletins under the title of "Quigley Products."

Surface Condensers

Ingersoll-Rand Company announces a new 36-page booklet on surface condensers. Among the subjects discussed are structural and design features; steam penetration; air removal equipment; marine condensers; cross-flow condensers; essentials of a condenser plant; condenser accessories and pumping equipment. The bulletin contains technical information not usually present in a bulletin of this type. More than 70 illustrations, including typical installations, and cross-sectional views are included.

Synthetic Rubber

"The Five Commercial Types of Synthetic Rubber" is the title of a 40-page booklet issued by the United States Rubber Company. This attractive publication traces the development of synthetic rubber from its laboratory beginnings, describes the properties of the commercial synthetic rubbers, and relates briefly the part played by the United States Rubber Company in the development, manufacture and use of its products. The publication includes photographic illustrations of synthetic rubber manufacture, many diagrams and a chart giving the relative physical and chemical properties of natural rubber and of five types of synthetic rubber.

Temperature Instruments

Leeds & Northrup Company has issued a 36-page catalog (N-33-163) describing its line of Micromax Temperature Recorders for use with thermocouples or with thermohm resistance thermometer bulbs. Applications to temperature measurement of steam, feedwater and cooling water, and to fuel, combustion air and flue gas are described in detail. Also described is an optical pyrometer for checking fuel bed and other furnace temperatures.

Used Material and Equipment

The Special Projects Salvage Branch of the Salvage Division, WPB, is publishing a bi-monthly publication entitled "Available Used Material and Equipment Bulletin," which is distributed to approximately 3000 government procurement officers and contractors, including the services and other war agencies such as Lend-Lease, Board of Economic Warfare, etc., covering most of the market for war uses. If any material or equipment listed in this bulletin can be put to use by these agencies they contact the owner for purchase, and the listing is terminated. If not sold within a stipulated period after listing (usually 60 days) the Regional Office of the WPB takes every possible step to move the material as scrap. Listing of materials is possible only after investigation and reporting of the project has been made.

Variable Speed Transmission

Reeves Pulley Company has issued a 16-page catalog (TR-432) describing its new Reducer-Type Transmission which combines variable speed mechanism and gear reducer in a single compact unit. This is a colorful bulletin admirably illustrated with unit, installation and phantom views, and giving engineering data and rating tables necessary for the selection of a unit of the proper size.

Water Technology

A 10-page bulletin (Technical Paper No. 86) entitled "TAPPI Survey of Water Technology, 1942" has been issued by W. H. & L. D. Betz. This survey was presented by Dr. Lewis B. Miller at the annual meeting of the Technical Association of the Pulp and Paper Industry. The bulletin reviews the progress in industrial water conditioning during 1942 and is divided into ten subjects: Water in the War Production Program; Water—The Raw Material; Process Water for Industry; Water Treatment, Water Analysis; Corrosion; Boiler Feedwater and Cooling Water; Bacteriology and Biochemistry of Water; Equipment; Recent Books on Water and Related Subjects. Under each of these headings appears a listing of important articles written on the subject during the past year.

Welded Steel Tubing

"Manual of Welded Steel Tubing for Heat Exchanger and Condenser Use" is the title of a 20-page bulletin compiled by the Formed Steel Tube Institute, Cleveland, Ohio. This publication constitutes a buyer's guide and reference data book for the use of purchasing agents, design engineers and others concerned with the procurement of welded carbon and alloy steel tubing for heat transfer equipment. The booklet describes the welded tube manufacturing process and is amply illustrated. Latter portions of the manual furnish fabrication data and extensive tables of tube properties, surface areas, carrying capacities, displacements, etc.

Possible Coal Car Shortage

Joseph B. Eastman, Director of the Office of Defense Transportation, has urged speedy unloading of all coal held in cars at destination points so that the cars can be returned to the mines promptly for reloading. While enough empty cars accumulated at the mines during the stoppage to take care of renewed production for several days, a car shortage will develop unless cars now under load at destination are unloaded and started back promptly.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1943 Water Tube		1942 Water Tube		1943 Fire Tube		1942 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	11	64,169	197	1,590,796	18	22,854	52	59,476
Feb.	35	175,308	216	1,467,900	244	151,055	58	83,647
Mar.	32	149,983	268	1,487,505	17	25,043	60	62,679
Apr.	96	354,246	422	2,402,579	22	33,231	46	61,054
Jan.-Mar., incl.	174	743,706	1,103	6,948,780	301	232,183	216	266,856

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period January to April (incl.) 1943, 6,800,000 lb per hr; in 1942, 56,017,000 lb per hr.

†Mechanical Stoker Sales

	1943 Water Tube		1942 Water Tube		1943 Fire Tube		1942 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	134	48,448	87	42,876	457	31,623	159	24,135
Feb.	104	34,858	131	55,001	575	83,673	185	26,889
Mar.	114	48,367	84	46,055	573	77,951	210	31,329
Apr.	99	33,781	102	49,061	433	64,172	313	39,877
Jan.-Mar., incl.	451	165,454	404	192,993	2,038	257,419	867	122,230

† Capacity over 300 lb of coal per hr.
NOTE: Publication of monthly report on Pulverizers discontinued.

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